CERTIFICATION OF APPROVAL

RESPONSES OF OTRC CLASSIC SPAR SUBJECTED TO RANDOM WAVES

by

Rosni Binti Abdul Halim

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi Petronas
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Approved by,

....

(AP Dr Kurian V John)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own respect as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(ROSNI BINTI ABDUL HALIM)

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TABLE OF CONTENT

ABSTRACT

As the deepwater exploration has become the most popular topic discussed in oil and gas industries nowadays, many floating structures have been proposed for cost effective solution. This project is to conduct a detailed literature survey about Spar Technology, Classic Spars, Existing Spars, Dynamic Analysis and Model Studies. But the more specific objectives for this project are to conduct a dynamic analysis study about how classic spars will responses to random waves. A detailed literature review was done to achieve the best understanding about the topic. From the literature reviewed, it gives a vast understanding and knowledge about the new technologies in oil and gas industries. Petronas Carigali Sdn Bhd (PCSB) have provided convenience information such as the environmental parameter, normal load acting on a spar platform and dimension for Kikeh Spars, this has made the research easier. Simple dynamic rigid body analyses in time domain were done in order to see how the classic spars acting with due to the environmental data provided. Through this project it proved that spar is a very stable structures which can be installed in unlimited water depth and stable with the loading applied onto it. The project has given another alternative to the oil exploration in Malaysia and proved that Malaysia oil and gas exploration can be widening to the next stage which is deepwater exploration.

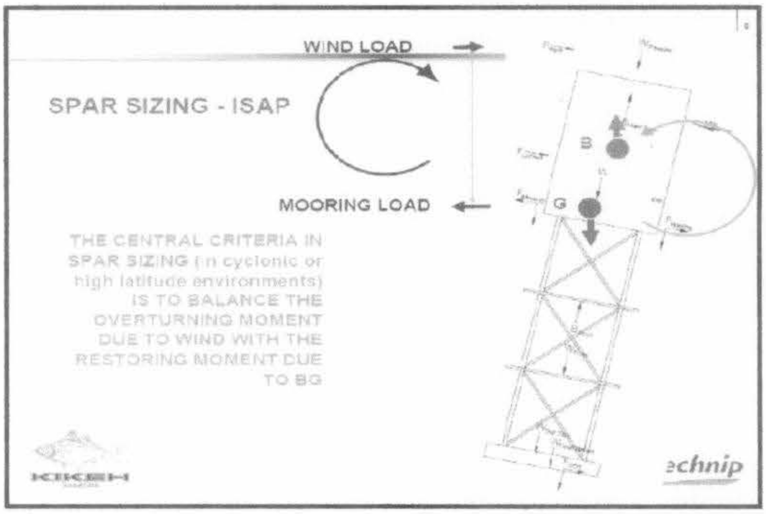
CHAPTER 1: INTRODUCTION

1.1 Background of Study

As offshore oil and gas exploration are pushed into deeper and deeper water, many innovative floating offshore structures are being proposed for cost savings. To reduce wave induced motion, the natural frequency of these newly proposed offshore structures are designed to be far away from the peak frequency of the force power spectra. Spar platforms are one such compliant offshore floating structure used for deep water applications for the drilling, production, processing, storage, and offloading of ocean deposits. It is being considered as the next generation of deep water offshore structures by many oil companies. It consists of a vertical cylinder, which floats vertically in the water. The structure floats so deep in the water that the wave action at the surface is dampened by the counter balance effect of the structure weight. Fin like structures called strakes, attached in a helical fashion around the exterior of the cylinder, act to break the water flow against the structure, further enhancing the stability. Station keeping is provided by lateral, multi-component anchor lines attached to the hull near its center of pitch for low dynamic loading. The analysis, design and operation of Spar platform turn out to be a difficult job, primarily because of the uncertainties associated with the specification of the environmental loads. The present generation of Spar platform has the following features: (*A.K Agarwal, A.K Jain "Dynamic Behavior of Offshore Spar Platform under Regular Waves" Engineering 30 (2003) 487-516*)

(a) It can be operated till 3000 Mts. depth of water from full drilling and production to production only,
(b) It can have a large range of topside payloads,
(c) Rigid steel production risers are supported in the center well by separate buoyancy cans,

(d) It is always stable because center of buoyancy (CB) is above the center of gravity (CG)



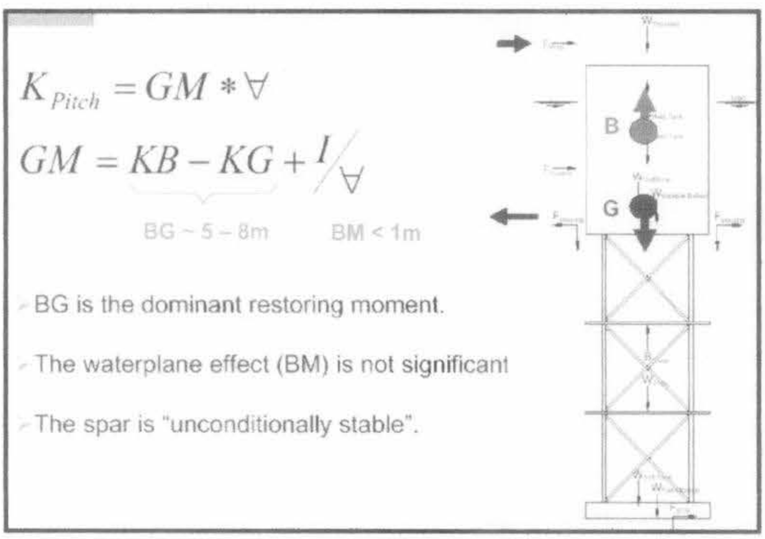


Figure 1.1.1: shows how the spars is stable (*Deepwater Seminar material Source by PCSB*)

(e) It has favorable motions compared to other floating structures,
(f) It can have a steel or concrete hull,
(g) It has minimum hull /deck interface,
(h) Oil can be stored at low marginal cost,
(i) It has sea keeping characteristics superior to all other mobile drilling units,

(j) It can be used as a mobile drilling rig,

(k) The mooring system is easy to install, operate and relocate

Figure 1.1.2: Loading mooring line pull in winch on upended hull on 20th October 2006
(PCSB Deepwater Seminar materials)

(l) The risers, which normally take breathing in the wave zone from high waves on semi-submersible, drilling units would be protected inside the Spar platform. Sea motion inside the Spar platform center well would be minimal.

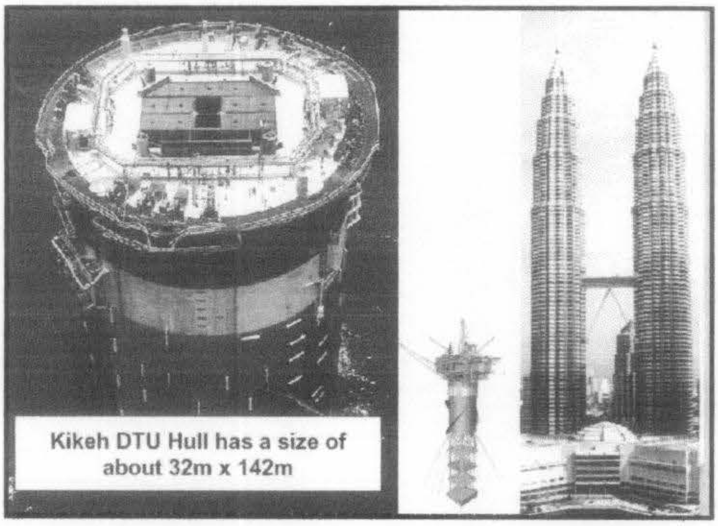


Figure 1.1.3: Visual view about comparison the Kikeh spar with the KLCC (*PCSB Deepwater Seminar materials)*

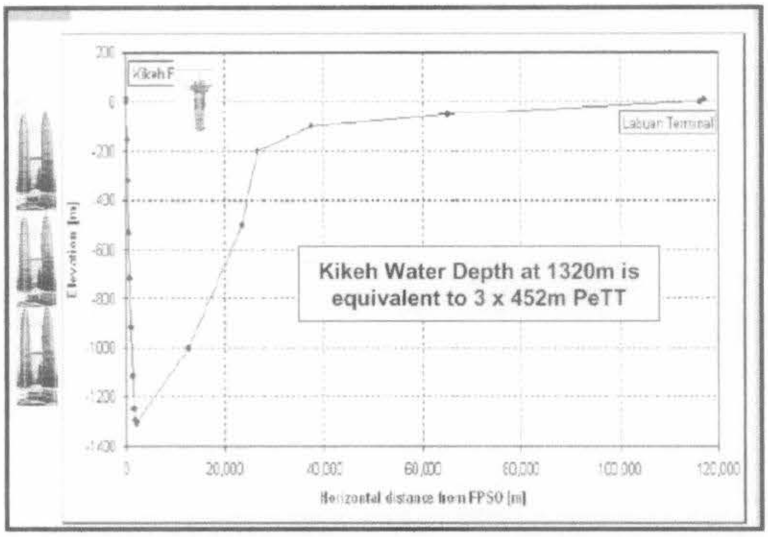


Figure 1.1.4: Visual comparison the water depth in Kikeh field (*PCSB Deepwater Seminar materials)*

1.2 Problem Statement

In recent years in oil and gas industries in Malaysia people has talk about deepwater exploration. This is due to the shortage of crude reservoirs in shallow water in Malaysia, and expected to dry up in 20 years. So the alternative solution for this problem is to do the exploration in deepwater. Deepwater and ultra-deepwater oil operations are expected to increase by 200% ~ 300% over the next ten years. (*Technip Deepwater Seminar materials)*

The floating structure will lower the fabrication cost compared with fixed offshore structures (conventional jacket) by reducing the complexity of steel fabrication by simplifying the design concept in term of to consider more environmental load that will be acting onto the fixed offshore structure if it being installed in such a deepwater.

In year 2006, Malaysia has succeeded to fabricate and install a truss spar in Kikeh field at offshore Sabah. The spar is the only spar had been installed outside of Gulf of Mexico. In 1300m water depth flexible riser were being used. The main concern in this project is to know the motion and displacement of the spar due to random waves.

1.3 Objective and Scope of Study

Objectives of the project

1. to prepare a detailed literature survey about the Spar Technology, Classic Spars, Existing Spars, Dynamic Analysis and Model Studies.
2. To determine the movements of the spar such as surge, heave and pitch by conducting dynamic analysis in time domain.
3. To make a parametric study of the above responses changing parameters like water depth and wave spectrum will be carried out using Microsoft excel.

CHAPTER 2: LITERATURE REVIEW AND THEORY

2.1 Linear Airy Wave Theory

The simplest and most useful of all wave theories is the small amplitude wave theory. This wave theory is also known as Airy theory or sinusoidal wave theory. It is based on the assumption that the wave height is small compared to the wave length or water depth. This assumption allows the free surface boundary conditions to be linearized by dropping wave height terms which are beyond the first order. This assumption also allows the free surface conditions to be satisfied at the mean water level, rather than at the oscillating free surface. (*examples for Linear Airy Wave Theory is in the results*)

2.2 Morison Equation

The Morison equation was developed by Morison, O'Brien, Johnson, and Shaaf (1950) in describing the horizontal wave forces acting on a vertical pile which extends from the bottom through the free surface. Morison, *et al.* proposed that the force exerted by unbroken surface waves on a vertical cylindrical pile which extends from the bottom through the free surface is composed of two components, inertia and drag. (*examples for Morrison Equation is in the result)*

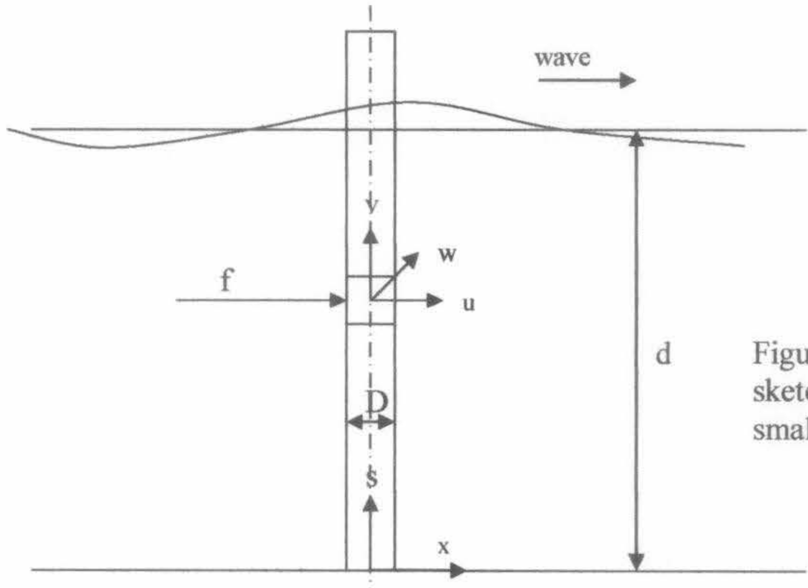


Figure 2.2.1: Definitio sketch for wave forces o small diameter cylinder

Morison Equation general equation:

$$Df_I = C_M \rho \pi/4\ D2\delta_u/\delta_t\ ds$$

2.3 Structural Model

The Spar platform is modeled as a rigid cylinder with six degrees-of-freedom (i.e. three displacement degrees-of-freedom i.e. Surge, Sway and Heave along *X, Y* and Z axis and three rotational degree-of-freedom i.e. Roll, Pitch and Yaw about *X, Y* and Z axis) at its center of gravity, CG. The Spar platform is assumed to be closed at its keel. The stability and stiffness is provided by a number of mooring lines attached near the center of gravity for low dynamic positioning of the Spar platforms. When the platform deflects the movement will take place in a plane of symmetry of the mooring system, the resultant horizontal force will also occur in this plane and the behavior will be 2 dimensional. It is the force and displacement (excursion) at this attachment point that is of fundamental importance for the overall analysis of the platforms. It is assumed that the Spar platform is connected to the sea floor by four multi component catenary mooring lines placed perpendicular to each other, which are attached to the Spar platform at the fairleads. The development of Spar platform model for dynamic analysis involves the formulation of a nonlinear stiffness matrix considering mooring line tension fluctuations due to variable buoyancy and other nonlinearities. The model considers the coupled behaviors of a Spar platform for various degrees-of-freedom. Figure 2.3.1 shows a classic offshore Spar platform.

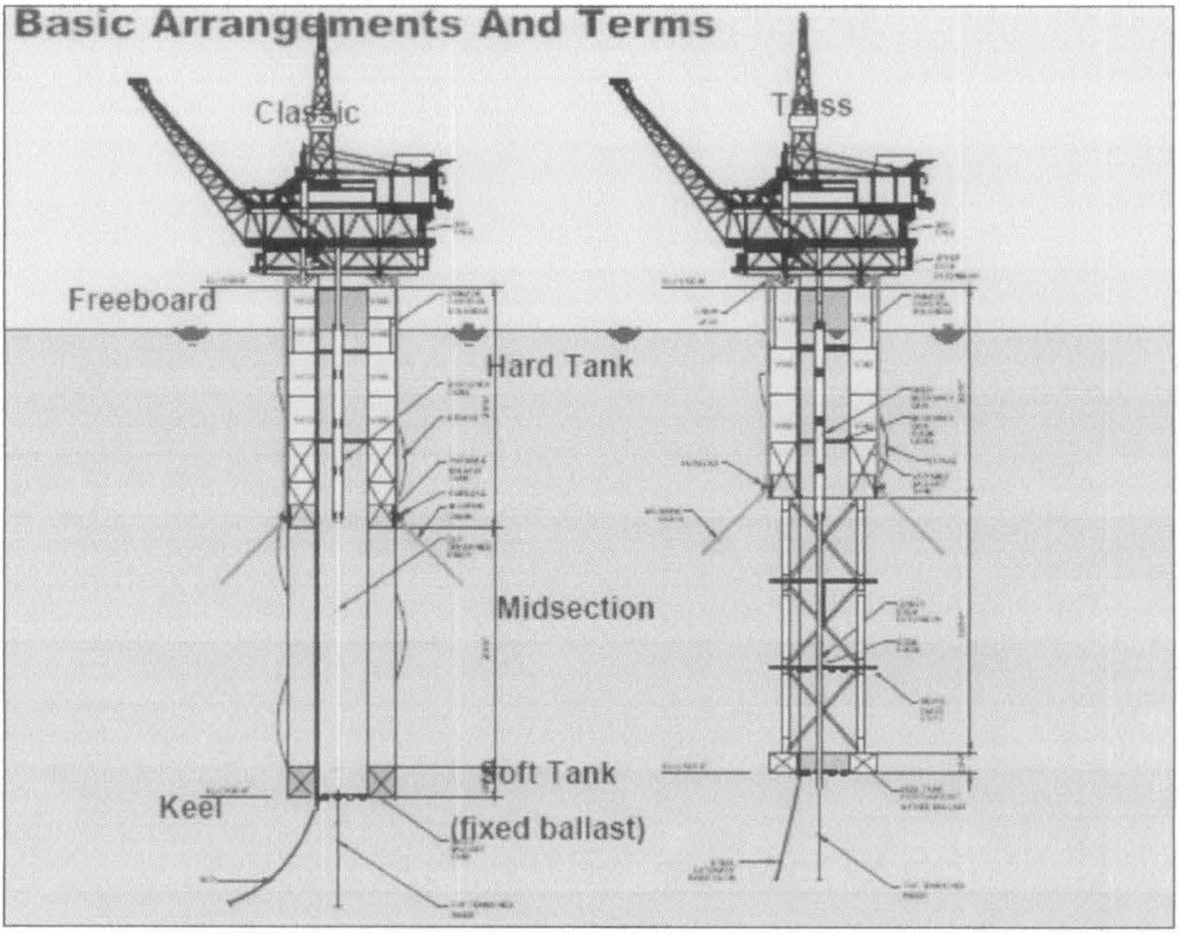


Figure 2.3.1: Basic arrangement and terms of Classic Spar and Truss Spar (*deepwater seminar materials by Technip*)

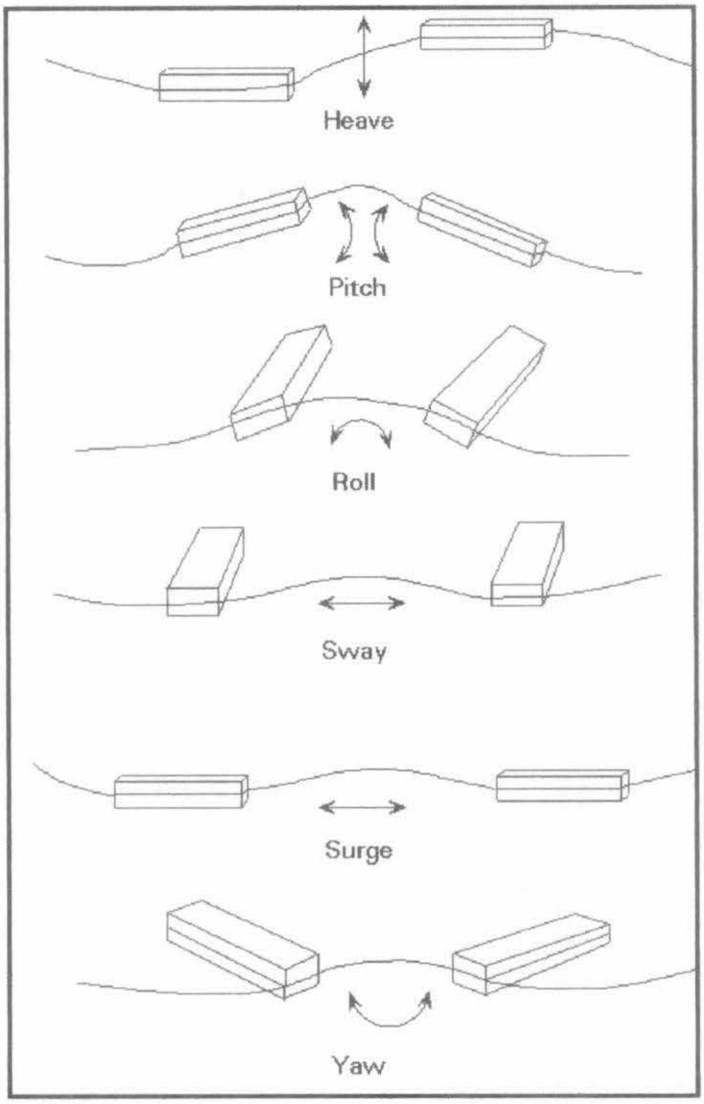


Figure 2.3.2: Types of motion of a floating structure (six degree of freedom) *(Design Of Offshore Structures Notes, Chapter 7)*

2.4 Assumptions and Structural Idealization

The platform and the mooring lines are treated as a single system and the analysis is carried out for the six degrees-of-freedom under the environmental loads. The following assumptions have been made in the analysis:

1. Initial pretension in all mooring lines is equal. However, total pretension changes with the motion of the Spar platform,

2. Wave forces are estimated at the instantaneous equilibrium position of the Spar platform by Morison's equation using Airy's linear wave theory. The wave diffraction effects have been neglected,
3. Integration of fluid inertia and drag forces are carried out up to the actual level of submergence according to the stretching modifications considered in the analysis,
4. Wave force coefficients, *Cd* and *Cm* are independent of frequencies as well as constant over the water depth,
5. Current velocity has not been considered and also the interaction of wave and current has been ignored,
6. Wind forces have been neglected,
7. Change in pretension in mooring line is calculated at each time step, and writing the equation of equilibrium at that time step modifies the elements of the stiffness matrix,
8. The platform is considered as a rigid body having six degrees-of-freedom,
9. Platform has been considered symmetrical along surge axis. Directionality of wave approach to the structure has been ignored in the analysis and only uni-directional wave train is considered,
10. The damping matrix has been assumed to be mass and stiffness proportional, based on the initial values.

2.5 Pierson-Moskowitz Spectrum

In 1964 Pierson and Moskowitz (1964) proposed a new formula for an energy spectrum distribution of a wind generated sea state based on similarity theory of Kitaigorodskii and more accurate recorded data. This spectrum commonly known as P-M model has since been extensively used by ocean engineers as one of the most representative for water all over the world. It has found many applications in the design of offshore structures.

The P-M spectral model describes a fully-developed sea determined by one parameter, namely, the wind speed. The fetch and duration are considered infinite. For the applicability of such a model, the wind has to blow over a large area at a nearly constant speed for many hours prior to the time when the wave record is obtained and the wind should not change its direction more than a certain specified small amount. In spite of these assumptions, the P-M model has been found to be useful in representing a severe storm wave in offshore structure design. The application of this theory can be see in result. General equation for Pierson-Moskowitz spectrum

$$S(f) = \alpha g^2/(2\pi)^4 f^{-5} \exp[-1.25\,(f/f_o)^{-4}]$$

2.6 Simulation of Wave Profile from Spectra

It is sometimes necessary to calculate the height of a wave at a particular frequency form an energy density spectrum curve. At a frequency, f_1, the energy density is $S(f_1)$. The wave height at this frequency is obtained as follows

$$H(f_1) = 2(2S(f_1)\Delta f)^{0.5}$$

Then, for a given horizontal coordinate, x, which is the location at which the wave profile is desired, and time, t, which is incremented, the wave profile is computed from

$$\eta(x,t) = \Sigma\, H(n)/2\ \cos[k(n)x - 2\pi f(n)t + \varepsilon(n)]$$

2.7 Motion-Response Spectrum

If a structure is free to move its motion may be critical near the resonance of the structure. Therefore, it is important to study the overall response of the structure due to a design-wave spectrum. In this case, the response-amplitude operators are written relating the dynamic motion spectrum is obtained from the force spectrum. Or equivalently, from the wave spectrum. If the relationship between the motion and force is linear, the conversion is relatively straightforward.

Consider that the motion of the structure in a particular direction, x, is ucoupled and can be modeled by a simple linearly damped spring-mass system. If m is the total mass of the system, K is its spring constant, and C is the damping coefficient, then the equation of motion is

$$mx'' + Cx' + Kx = F_1 \cos \omega t$$

where F_1 is the inertia-force amplitude which is linear with wave height. Note that Cx' is a linear damping term. The displacement, x, is the motion in a particular direction, e.g., surge, sway, or heave. The quantities x' and x" are corresponding velocity and acceleration, respectively. If the solution is assumed to take the form

$$x = X \cos(\omega t + \beta)$$

the displacement function can be written as

$$X(t) = [\ (F_I / (H/2))/[(K - m\omega^2)^2 + (C\omega)^2]^{1/2}]\ \eta_\beta(t)$$

Where β is the phase difference between x(t) and $\eta(t)$. This relationship can be transformed to obtain the motion spectrum in terms of the wave spectrum and RAO.

$$S_x(\omega) = [\ (F_I / (H/2))/[(K - m\omega^2)^2 + (C\omega)^2]^{1/2}]^2\ S(\omega)$$

Thus, for a linearly damped dyamic system, the motion-response spectrum can be obtained in the conventional way with an RAO given by the terms inside the bracket.

**All the Theories are from S.K Chakrabarti "Hydrodynamics of Offshore Structures)*

CHAPTER 3: METHODOLOGY

1. Conducted a detailed literature survey about the Spar Technology, Classic Spars, Existing Spars, and Dynamic Analysis & Model Studies.

   During this step all theory and literature review were searched and collected. Because of the understanding about the topic is minimal, more effort needed to find the past research about the topic. Try to define the term and jargon that usually used in the industry. The parameter and all information about the existing spar were collected. This information is important to do the dynamic analysis.

2. Conduct a simple dynamic rigid body analysis for classic spar subjected to random waves

   From the information collected, a simple dynamic rigid body analysis subjected to random waves were carried out.

   i. Morrison Equation is used to find the resultant force acting to the spar. The resultant force will be presented for every meter (submerge part).
   ii. Pierson-Moskowitz Spectrum will present the energy distribution subjected to waves.
   iii. Simulation of wave profile will shows the model waves the structure will be tested.
   iv. Motion response spectrum will presented the responses of the structure to the model waves.

3. Conduct model studies on classic spar and compare the same with theoretical results.

CHAPTER 4:

RESULTS AND DISSCUSSION

4.1 CALCULATION AND RESULTS

4.1 Calculations and Results

Figure 4.1.1 shows the spar parameter that being considered during the calculation parts. In this chapter the airy wave theory, Morrison equation, Peirson-Moskowitz Spectrum, Simulation of wave profile from spectra and Motion response spectrum will be applied.

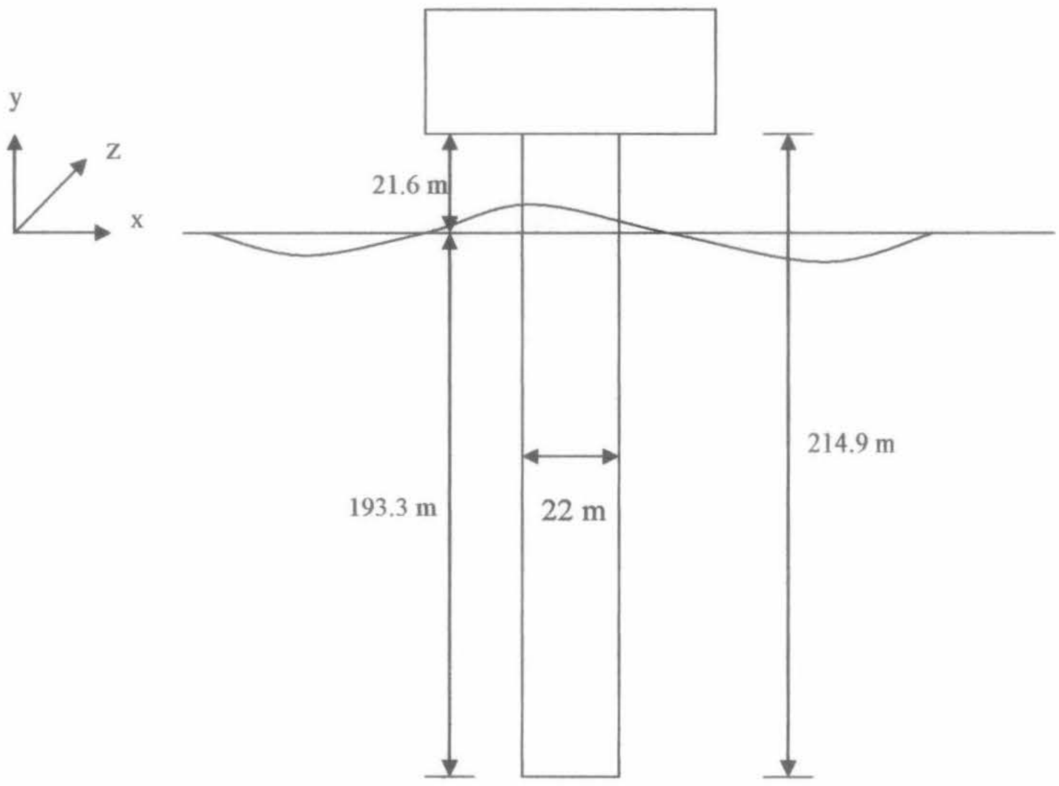


Figure 4.1.1: Neptune Classic Spar parameters

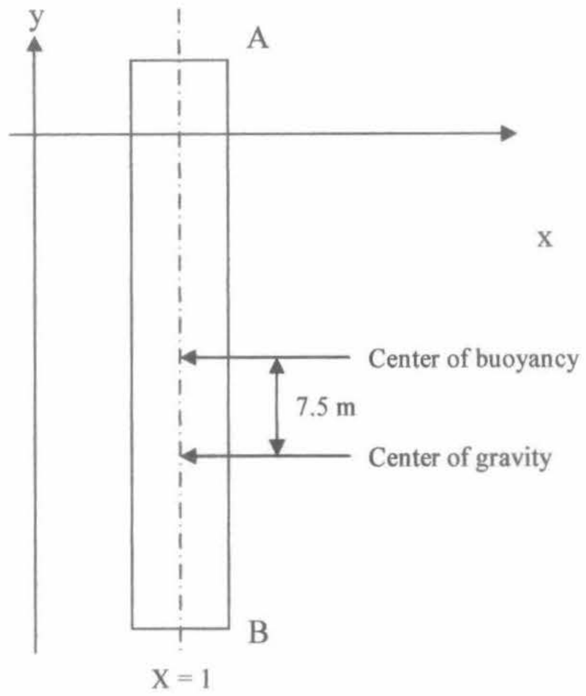


Figure 4.1.2: location of the center of buoyancy and center of gravity

Table 4.1.1 and Table 4.1.2 is the summary of the Neptune Classic spar platform and Hoover-Diana Classic spar parameter. All this parameter is obtain from the literature review done.

Neptune Classic Spar Profile	**Dimension**
Weight of the Hull	12.895×10^6 kg
Weight of the topsides with facilities	5.98742×10^6 kg
Height of the spar platform	214.9 m
Diameter of the spar platform	22 m
Distance of centre of gravity to buoyancy	7.5 m
Structural damping ratio	0.1
Wave period	10.8 sec
Wave Height	4.6 m
Water Depth	983 m
*Drag Coefficient C_d	0.65
*Inertia Coefficient C_m	1.6

Table 4.1.1: Dimension of Neptune Spar Platform and waves data.

Hoover-Diana Classic Spar Profile	Dimension
Weight of the Hull	35.831×10^6 kg
Weight of the topsides with facilities	26.5×10^6 kg
Height of the spar platform	214.9 m
Diameter of the spar platform	37.2 m
Distance of centre of gravity to buoyancy	7.5 m
Structural damping ratio	0.1
Wave period	10.8 sec
Wave Height	4.6 m
Water Depth	1463 m
*Drag Coefficient C_d	0.65
*Inertia Coefficient C_m	1.6

Table 4.1.2: Dimension of Hoover-Diana Spar Platform and waves data.

(**value taken from API-RP2A standard)*

Morrison equation

1) Assume coordinate of the structure is A (1,0,0)

   B (1,193.3,0)

2) Length of AB, L_{AB} = 193.3 m
3) Assume t = 1sec
4) $L_o = gT^2/2\pi = 9.806 \times 10.8^2 / 2\pi$

   = 182.04 m
5) L = 182.04 tan (2 π x50) / L

   L = 172.71 m

Airy wave theory applied here, where, with airy wave theory the wave length, wave height and wave steepness can be determined

6) $k = 2\pi/L = 0.0364$
7) $\omega = 2\pi/T = 0.5818$
8) $\theta = kx - \omega t$

   = 0.0364 – 0.5818

   = -0.5454 rad

9) Particle velocities;

Horizontal ;

$u = (\pi H)/T \, . \, (\cosh ks)/(\sinh kd) \, . \, \cos \theta$

Vertical;

$v = (\pi H)/T \, . \, (\sinh ks)/(\sinh kd) \, . \, \sin \theta$

10) Particle acceleration;

Horizontal;

$u' = (2\,\pi^2 H / T^2) \, . \, (\cosh ks)/(\sinh kd) \, . \, \sin \theta$

Vertical;

$v' = (-2\,\pi^2 H / T^2) \, . \, (\sinh ks)/(\sinh kd) \, . \, \cos \theta$

11) Unit vector

$$Cx = \frac{x_B - x_A}{L}$$

$$Cy = \frac{y_B - y_A}{L}$$

$$Cz = \frac{z_B - z_A}{L}$$

12) $u_x = u - Cx\,(Cxu + Cyv)$

$u_y = v - Cy\,(Cxu + Cyv)$

$u_z = - Cz\,(Cxu + Cyv)$

$w = (u_x^2 + u_y^2 + u_z^2)^{0.5}$

13) $u'_x = u' - Cx\,(Cxu' + Cyv')$

$u'_y = v' - Cy\,(Cxu' + Cyv')$

$u'_z = - Cz\,(Cxu' + Cyv')$

14) $f_x = C_M\,[(\rho\pi D^2)/4]\,u'_x + C_D\,(\rho D/2)\,|\,w|\,u_x$

$f_y = C_M\,[(\rho\pi D^2)/4]\,u'_y + C_D\,(\rho D/2)\,|\,w|\,u_y$

$f_z = C_M\,[(\rho\pi D^2)/4]\,u'_z + C_D\,(\rho D/2)\,|\,w|\,u_z$

From Morrison Equation we can determine the forces acting on the submerge hull. In the spreadsheet attached in the appendix A, shows the forces acting on the submerge hull were determined every meters.

Pierson-Moskowitz Spectrum

Frequency is varies from 0.005 – 0.195 with 0.01different ($\Delta f = 0.01$)

1) $\alpha = 0.0081$
2) $\omega_o^2 = 0.161g/H_s$
3) $f_o = \omega / 2\pi$
4) $S(f) = S(f) = \alpha g^2/(2\pi)^4 f^5 \exp[-1.25\,(f/f_o)^{-4}]$

Figure 4.1.3 below shows the P-M spectrum that represents the wave energy generated by the waves. From the spectrum the highest energy occurred around the wave period. This may be because the resonance may occurred when the frequency of the structure same as the natural wave frequency

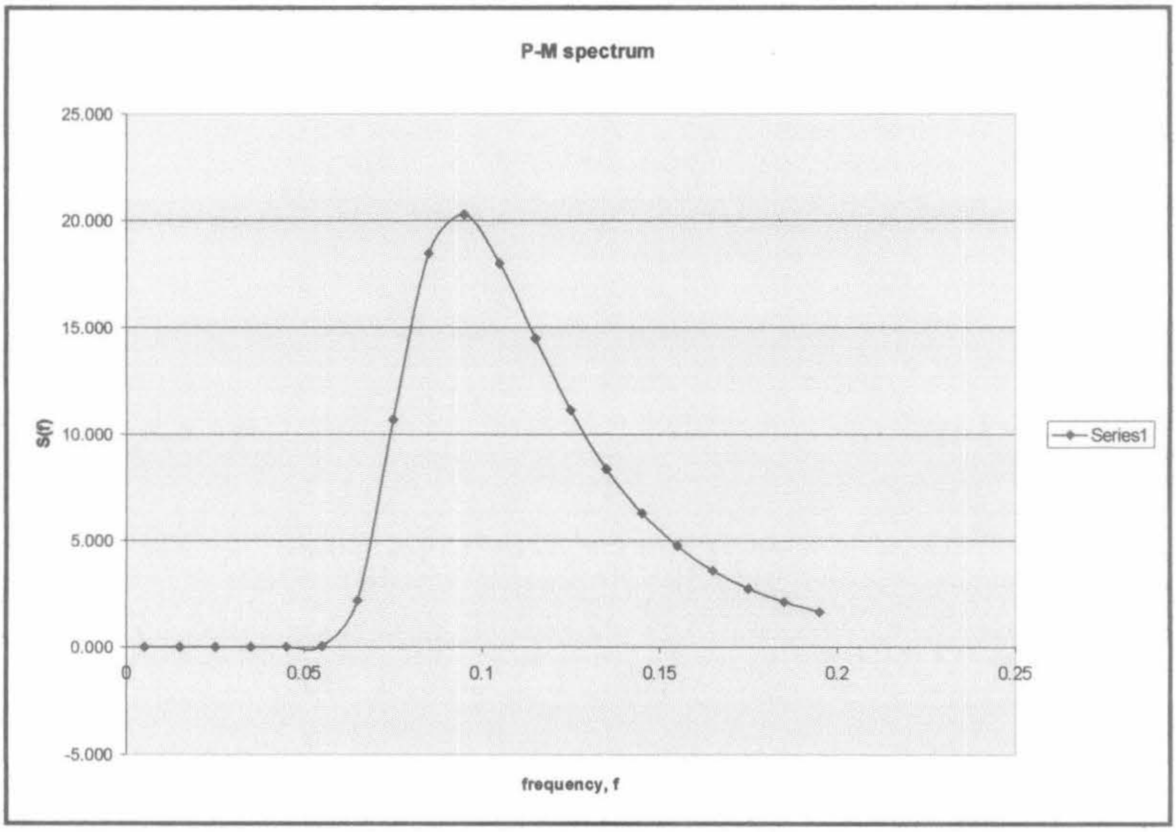


Figure 4.1.3: Pierson-Moskowitz Spectrum for Neptune Classic Spar

Simulation of wave profile from spectra

1) $H(f) = 2\,(2S(f_1)\,\Delta f)^{0.5}$
2) $\varepsilon\,(f_1) = 2\pi R_N$
3) $\eta(x,t) = \Sigma\, H(n)/2\ \cos[k(n)x - 2\pi f(n)t + \varepsilon(n)]$

Figure 4.1.4 shows the random wave profile from t = 0 until t = 200

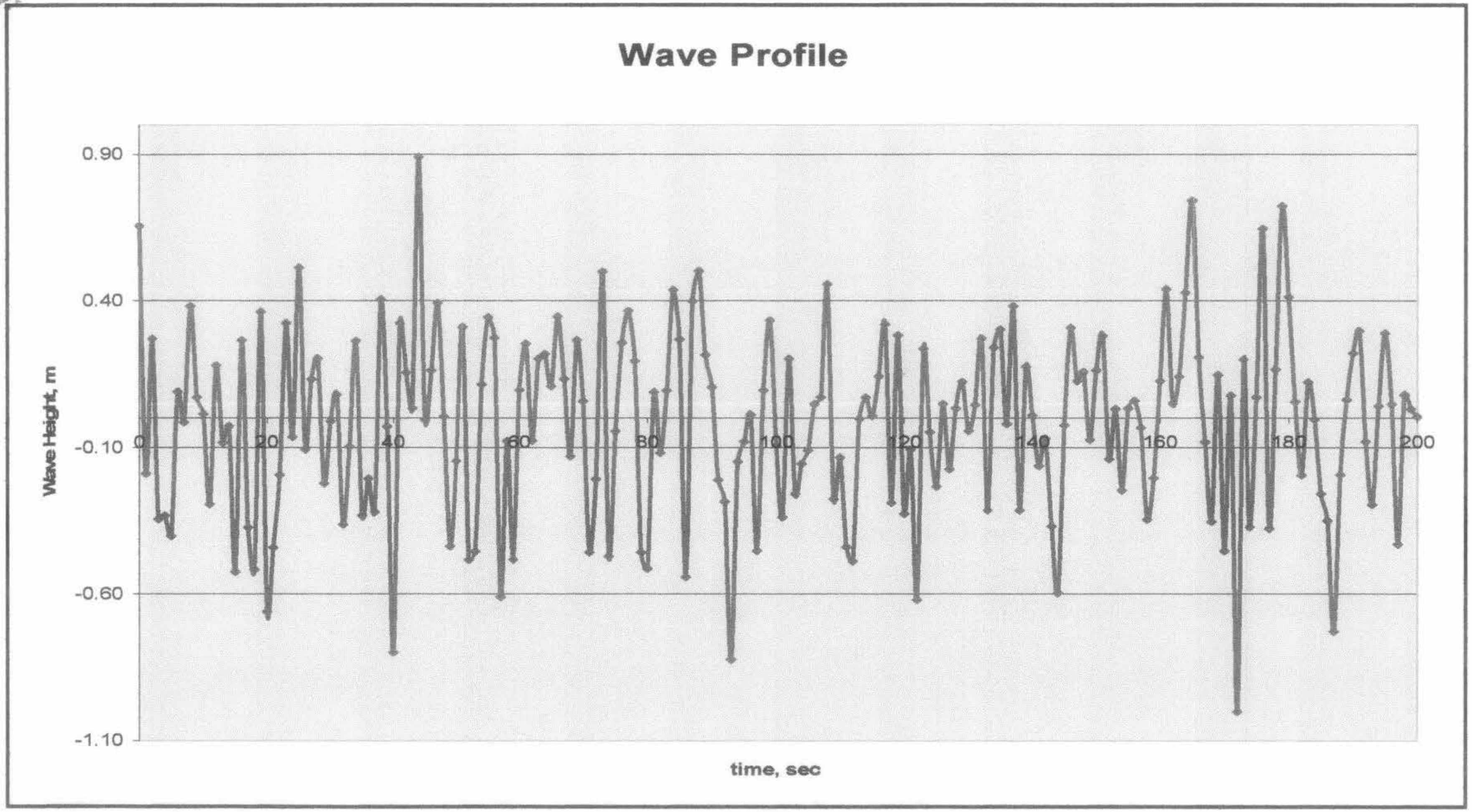


Figure 4.1.4: Random wave profile for Neptune Classic Spar

Motion-Response Spectrum

1) $S_x(f) = [\ (F_I / (H/2))/[(K - m\omega^2)^2 + (C\omega)^2]^{1/2}]^2\ S(f)$

Neptune Classic Spar

Mass of the topsides = 5.98742 x 10^6 kg

Mass of the spar = 12.895 x 10^6 kg

Total Mass

Mass for surge response

Mass of topsides + hull = 5.98742 x 10^6 + 12.895 x 10^6

= 18.88 x 10^6 kg

Added mass = π x $22^2/4$ x 193.24m x 1030 kg/m³ = 75.66 x 10^6 kg

Total mass for surge = 94.54 x 10^6 kg

Mass for Heave response

Mass of topsides + hull = 5.98742 x 10^6 + 12.895 x 10^6

= 18.88 x 10^6 kg

Added mass = π x $22^3/12$ x 1030 kg/m³ = 2.871 x 10^6 kg

Total mass for surge = 21.751 x 10^6 kg

Mass for Pitch response

Mass of topsides + hull = $5.98742 \times 10^6 + 12.895 \times 10^6$

$= 18.88 \times 10^6$ kg

Added mass = $\pi \times 22^2/4 \times 1030$ kg/m³ x draft (193.3m) = 75.684×10^6 kg

Total mass for surge = 94.564×10^6 kg

Responses	Total Mass (kg)
Surge	94.54×10^6
Heave	21.751×10^6
Pitch	94.564×10^6

Table 4.1.3: Summary of Neptune Classic Spar total mass for all responses

Hoover-Diana Classic Spar

Mass of the topsides = 26.5×10^6 kg

Mass of the spar = 35.831×10^6kg

Total Mass

Mass for surge response

Mass of topsides + hull = $26.5 \times 10^6 + 35.831 \times 10^6$

$= 62.331 \times 10^6$ kg

Added mass = $\pi \times 37.2^2/4 \times 193.24$m x 1030 kg/m³ = 21.63×10^7 kg

Total mass for surge = 27.87×10^7 kg

Mass for Heave response

Mass of topsides + hull = $26.5 \times 10^6 + 35.831 \times 10^6$

$= 62.331 \times 10^6$ kg

Added mass = $\pi \times 37.2^3/12 \times 1030$ kg/m³ = 13.88×10^6 kg

Total mass for surge = 76.211×10^6 kg

Mass for Pitch response

Mass of topsides + hull = $26.5 \times 10^6 + 35.831 \times 10^6$

$= 62.331 \times 10^6$ kg

Added mass = $\pi \times 37.2^2/4 \times 1030$ kg/m³ x draft (193.3m) = 21.64×10^7 kg

Total mass for surge = 27.87×10^7 kg

Responses	Total Mass (kg)
Surge	27.87×10^7
Heave	76.211×10^6
Pitch	27.87×10^7

Table 4.1.4: Summary of Hoover-Diana Classic Spar total mass for all responses

2) Stiffness;

General natural period for spars: *(Spar Joint Industry Project Organized by Deep Oil Technology, by OED Report No. 95503, ABS Americas, Houston, June 1995)*

Responses	Natural Period (s)
Surge	300 – 350
Heave	28 -29
Pitch	60 – 80

Table 4.1.5: General Natural Period for spar *(SPAR Joint Industry Project Organized by Deep Oil Technology by OED Report No. 9550, ABS Americas, Houston, June 1995)*

Neptune Classic Spar

<u>Surge Stiffness:</u>

Assume Surge natural period Tn = 215.4sec

Total Mass for Surge = 94.54×10^6 kg

$Tn = 2\pi / \omega_n$

$\omega_n = 0.0292$ rad/sec

$\omega_n = (k / m)^{1/2}$

$k = 8.0609 \times 10^4$ N/m

<u>Heave Stiffness:</u>

Assume Heave natural period Tn = 30 sec

Total Mass for Heave = 21.751×10^6 kg

$Tn = 2\pi / \omega_n$

$\omega_n = 0.2094$ rad/sec

$\omega_n = (k / m)^{1/2}$

$k = 9.5375 \times 10^5$ N/m

Pitch Stiffness:

Assume Pitch natural period Tn = 70 sec

Total Mass for Pitch = 94.564×10^6 kg

$Tn = 2\pi / \omega_n$

$\omega_n = 0.0898$ rad/sec

$\omega_n = (k / m)^{1/2}$

$k = 1.698 \times 10^6$ N/m

Responses	Stiffness (N/m)
Surge	**8.0609×10^4**
Heave	**9.5375×10^5**
Pitch	**1.698×10^6**

Table 4.1.6: Summary of Neptune Classic Spar stiffness for all responses

Hoover-Diana Classic Spar

Surge Stiffness:

Assume Surge natural period Tn = 325sec

Total Mass for Surge = 27.87×10^7 kg

$Tn = 2\pi / \omega_n$

$\omega_n = 0.0193$ rad/sec

$\omega_n = (k / m)^{1/2}$

$k = 10.417 \times 10^4$ N/m

Heave Stiffness:

Assume Heave natural period Tn = 29 sec

Total Mass for Heave = 76.211×10^6 kg

$Tn = 2\pi / \omega_n$

$\omega_n = 0.2167$ rad/sec

$\omega_n = (k / m)^{1/2}$

$k = 35.775 \times 10^5$ N/m

Pitch Stiffness:

Assume Pitch natural period Tn = 70 sec

Total Mass for Pitch = 27.87×10^7 kg

$Tn = 2\pi / \omega_n$

$\omega_n = 0.0898$ rad/sec

$\omega_n = (k / m)^{1/2}$

$k = 2.2474 \times 10^6$ N/m

Responses	Stiffness (N/m)
Surge	10.417×10^4
Heave	35.775×10^5
Pitch	2.2474×10^6

Table 4.1.7: Summary of Hoover- Diana Classic Spar stiffness for all responses

3) Damping coefficient, C

Neptune Classic Spar

<u>Damping coefficient, C for Surge</u>

$C = m \cdot 2\zeta\,\omega_n$ $\zeta = 0.1$

$= 94.54 \times 10^6 \times 2 \times 0.1 \times 0.0292$

$= 5.5211 \times 10^5$

<u>Damping coefficient, C for Heave</u>

$C = m \cdot 2\zeta\,\omega_n$ $\zeta = 0.1$

$= 21.751 \times 10^6 \times 2 \times 0.1 \times 0.2094$

$= 9.109 \times 10^5$

<u>Damping coefficient, C for Pitch</u>

$C = m \cdot 2\zeta\,\omega_n$ $\zeta = 0.1$

$= 94.546 \times 10^6 \times 2 \times 0.1 \times 0.0898$

$= 1.698 \times 10^6$

Responses	Damping coefficient, C
Surge	5.5211×10^5
Heave	9.109×10^5
Pitch	1.698×10^6

Table 4.1.8: Summary of damping coefficient for Neptune Classic Spar

Hoover-Diana Classic Spar

Damping coefficient, C for Surge

$C = m \cdot 2\zeta\,\omega_n$ $\zeta = 0.1$

$= 27.87 \times 10^7 \times 2 \times 0.1 \times 0.0193$

$= 10.758 \times 10^5$

Damping coefficient, C for Heave

$C = m \cdot 2\zeta\,\omega_n$ $\zeta = 0.1$

$= 76.211 \times 10^6 \times 2 \times 0.1 \times 0.2167$

$= 33.03 \times 10^5$

Damping coefficient, C for Pitch

$C = m \cdot 2\zeta\,\omega_n$ $\zeta = 0.1$

$= 27.87 \times 10^7 \times 2 \times 0.1 \times 0.0898$

$= 5.005 \times 10^6$

Responses	Damping coefficient, C
Surge	**10.758×10^5**
Heave	**33.03×10^5**
Pitch	**5.005×10^6**

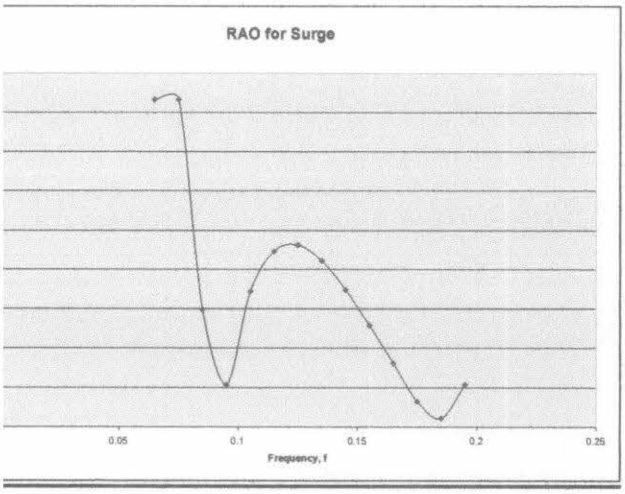
Table 4.1.9: Summary of damping coefficient for Hoover-Diana Classic Spar

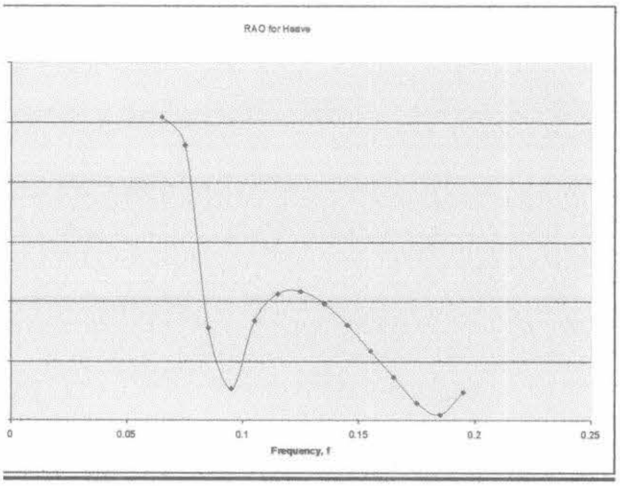
4) System frequency = 2 πf

Substitute all the values in equation; (equation in the bracket is RAO)

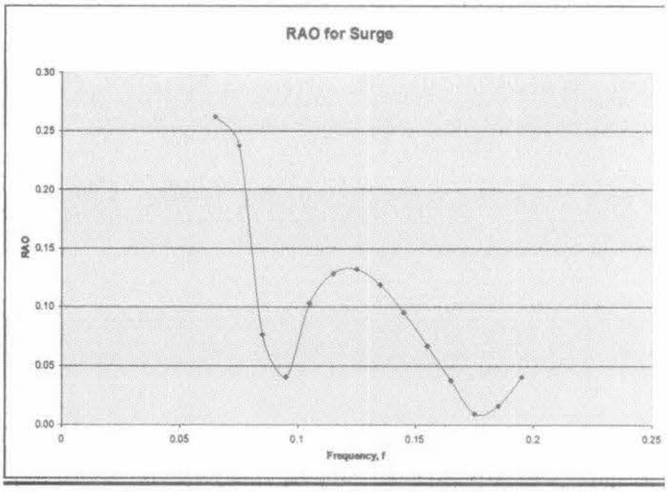
$$S_x(f) = [\ (F_I\ /\ (H/2))/[(K - m\omega^2)^2 + (C\omega)^2]^{1/2}]^2\ S(f)$$

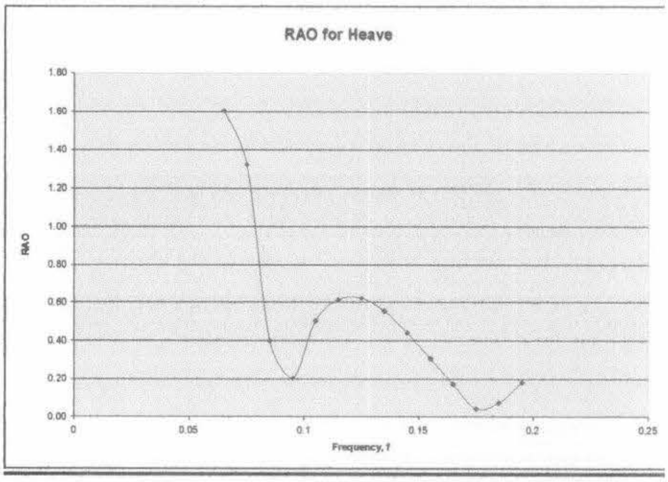
Neptune Classic Spar

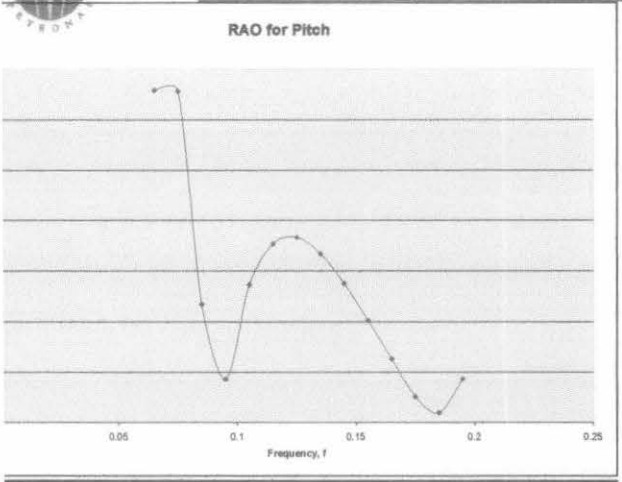




Hoover-Diana Classic Spar







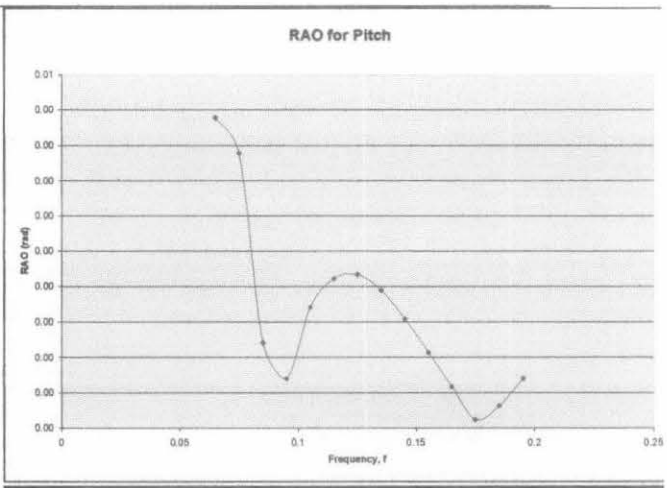


Figure 4.1.5: RAO graphs for Neptune and Hoover-Diana Classic Spar

Motion Response Graphs

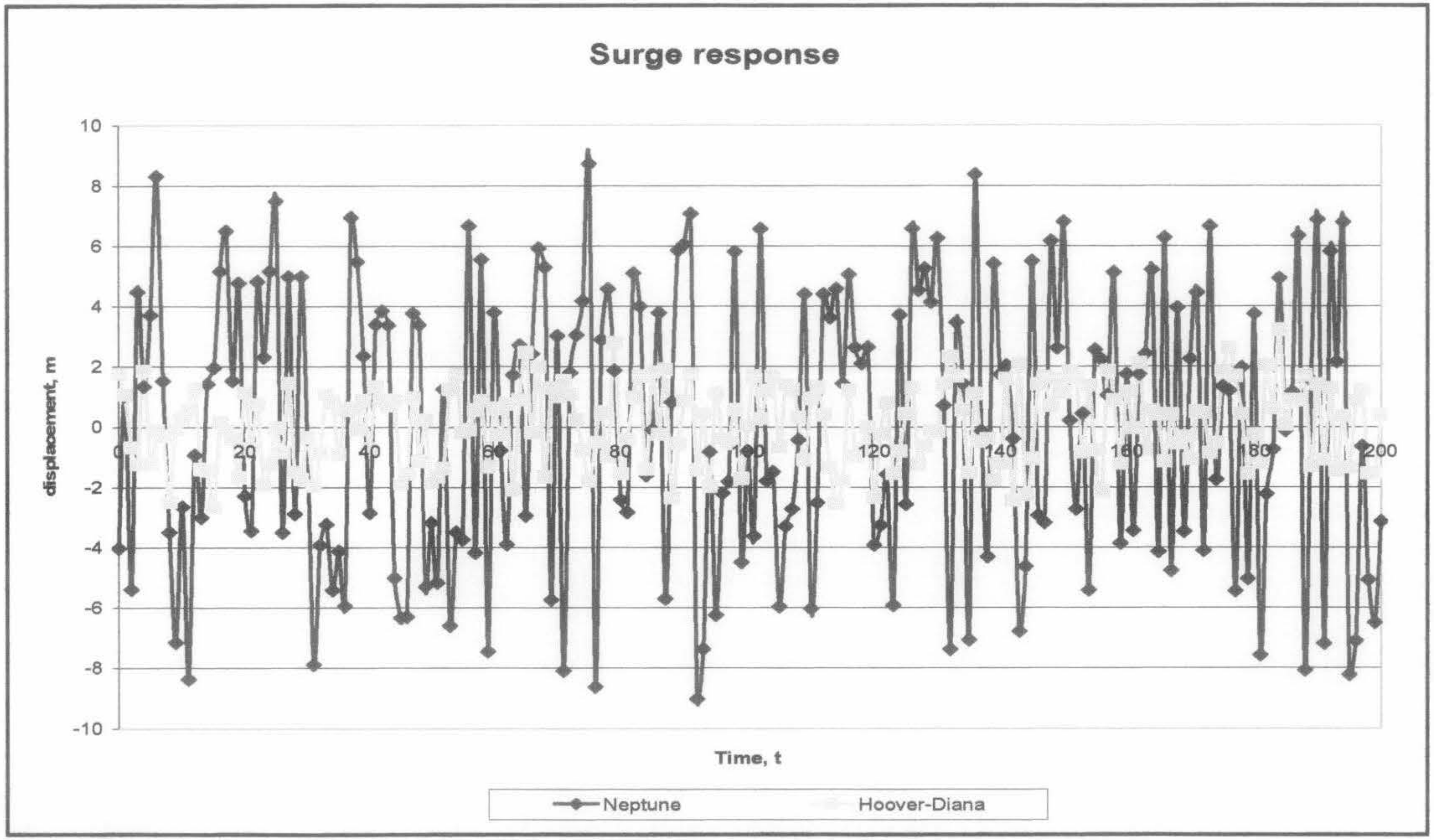


Figure 4.1.6: Surge response graph subjected to time

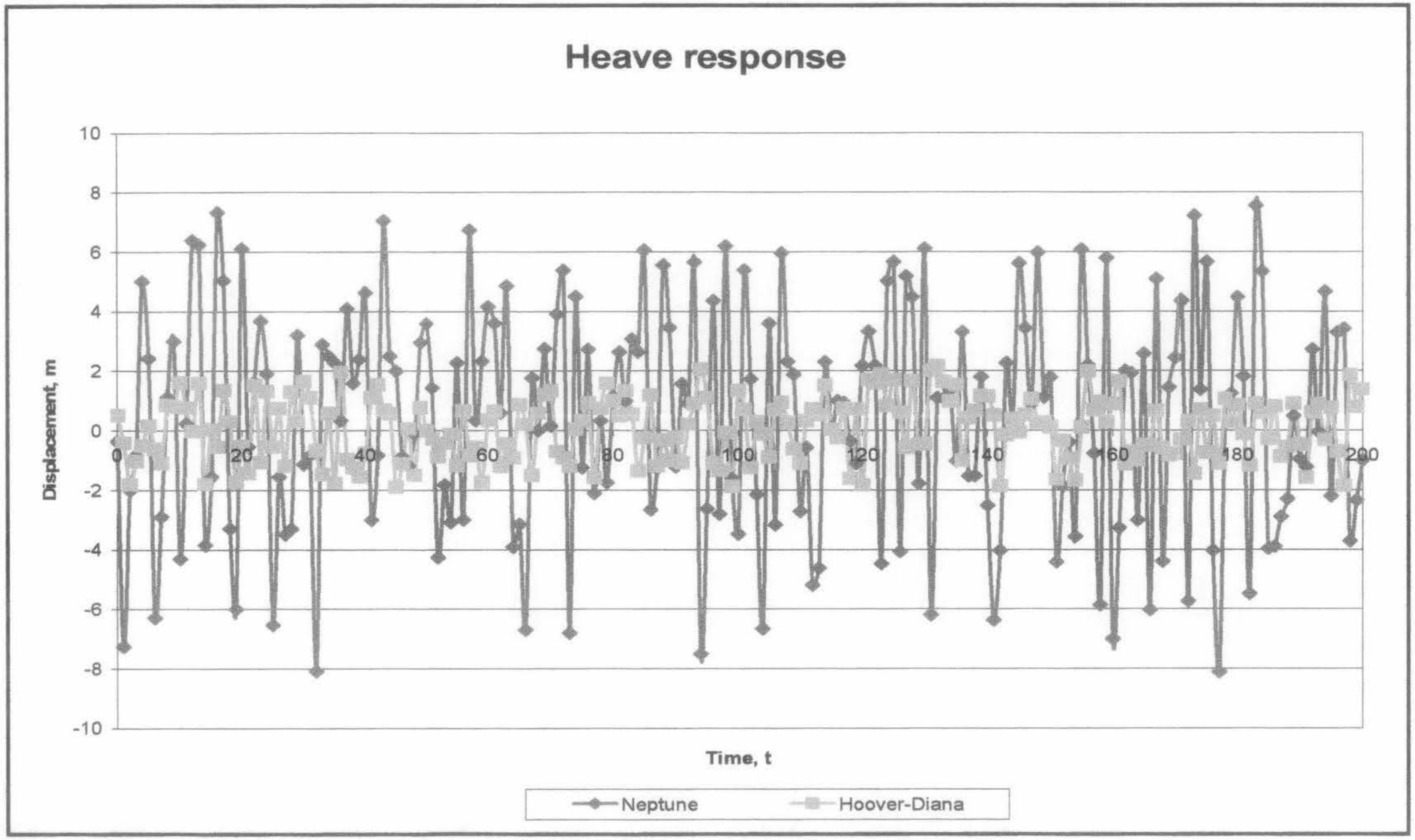


Figure 4.1.7: Heave response graph subjected to time

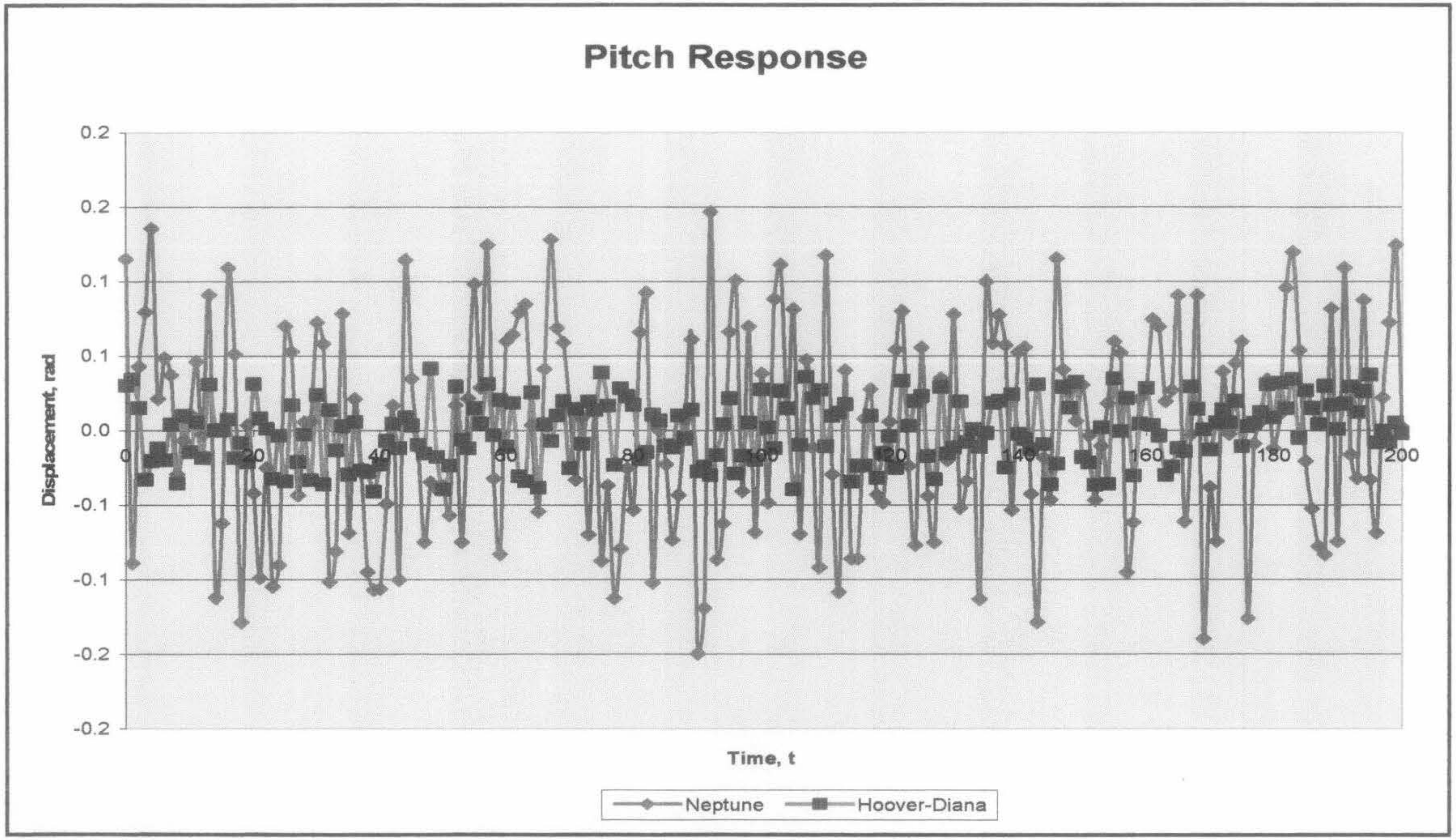


Figure 4.1.8: Pitch response graph subjected to time

* All the Equation were obtain from Hydrodynamics of Offshore Structures by *S.K. Chakrabarti*

4.2 Discussion

Figure 4.2.2 represent the plan and schematic elevation of Neptune Classic Spar platform and Hoover-Diana with *Kikeh field environmental loading*. Wind and current have not been studied herein. For this project only waves approach from x-axis direction has been considered.

Morrison equation gives the resultant force acting along the submerge draft of the both Classic Spar platforms. The resultant forces (refer to appendix A *Morrison equation)* calculated is only for the classic spar in vertical position. From the appendix A we can observed that resultant force for y and z –axis are zero. This is because we only considered the waves only come from one direction, x-axis. Figure 4.2.1 below can be interpreted that resultant force is higher at the surface of the sea, and the resultant force will decrease, approached nearly to zero as the water depth increases. This resultant force pattern will go the same for all submerge vertical cylinder.

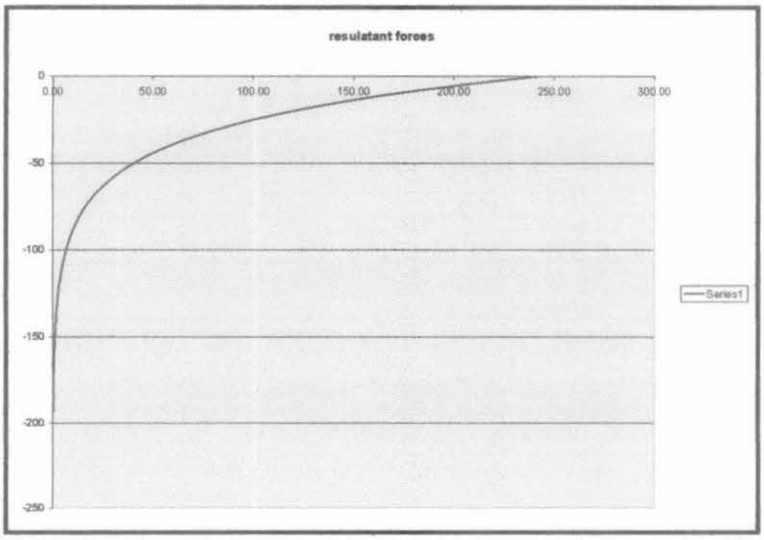


Figure 4.2.1: Resultant force of submerge draft for Neptune Classis Spar

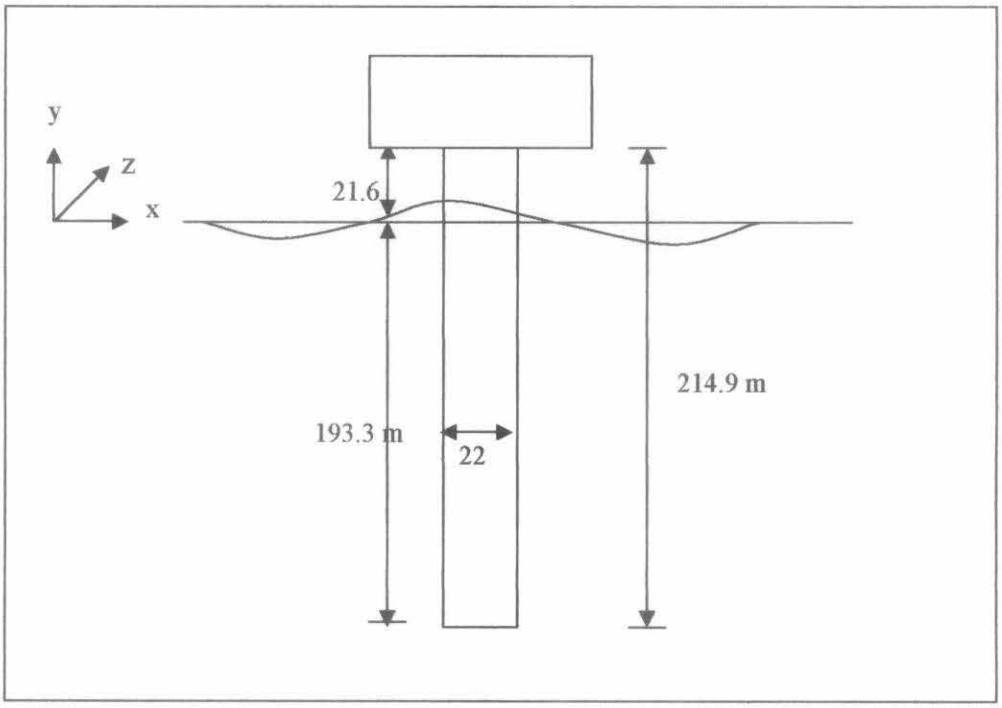


Figure 4.2.2: Spar parameters

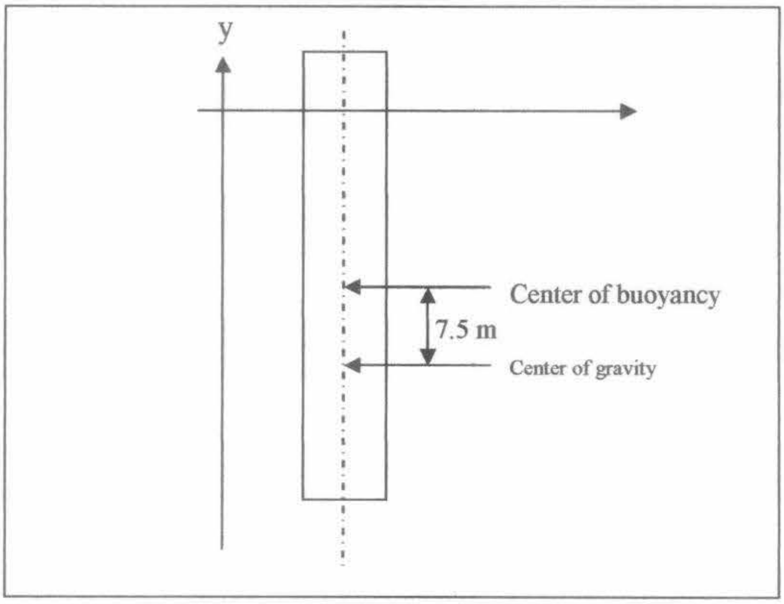


Figure 4.2.3: location of the center of buoyancy and center of gravity

Center of buoyancy of the for both hull is assumed to be located at the center of the submerge hull in this case the center of buoyancy is located at elevation -96.65 m from the mean sea level, and center of gravity (COG) of the hull is assumed to be located 7.5 m below the center of buoyancy of the hull. So, the elevation of COG is –104.15 m below the mean sea level. The COG and center of buoyancy for Neptune and Hoover-Diana were assume similar because the spar length and submerge hull (draft) are at the same length., Because of both center of buoyancy and COG had been determine the student can find the moment acting on the hull using the Morrison equation (*the spread sheet of morision equation will be attached in AppendixA)*.

Pierson-Moskowitz spectrum represents;

- Energy density vs. cyclic or circular frequency or period
- Energy vs. cyclic or circular frequency circular frequency or period

The simulation of wave profile from spectra have been done up to t=200 sec (*the spread sheet of the wave profile from spectra attached in Appendix B)*. This will give the random waves models that acting to the Neptune Classic Spar. Figure 4.2.4 shows the random waves profiles acting on the spar submerge daft.

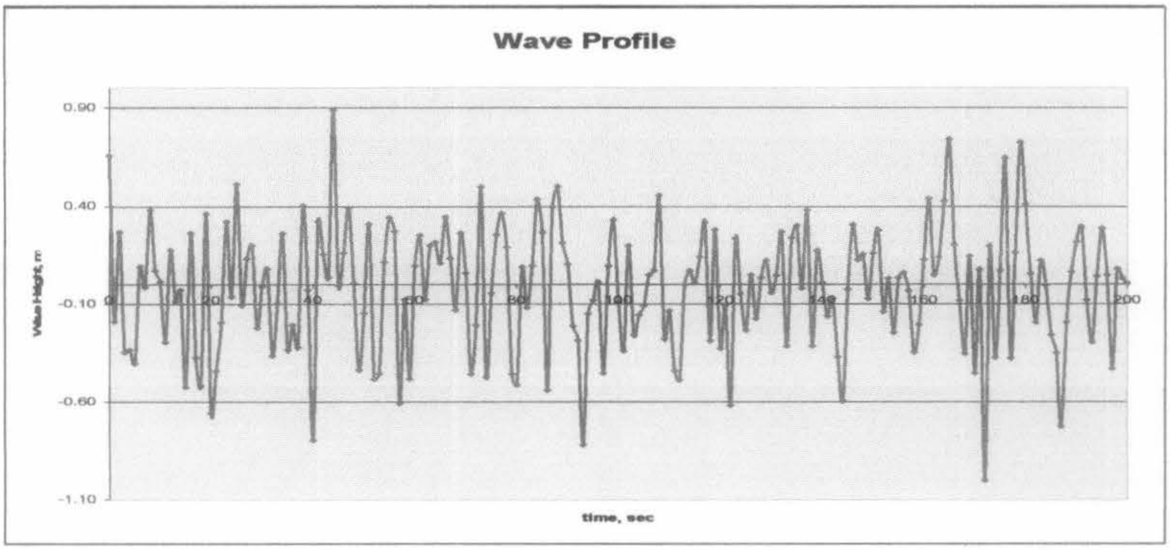
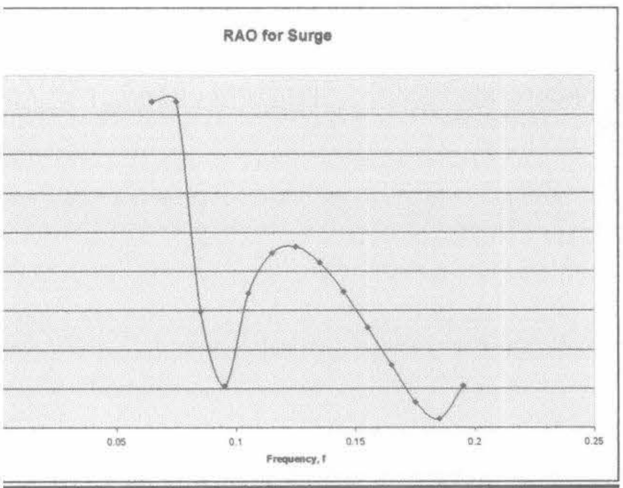
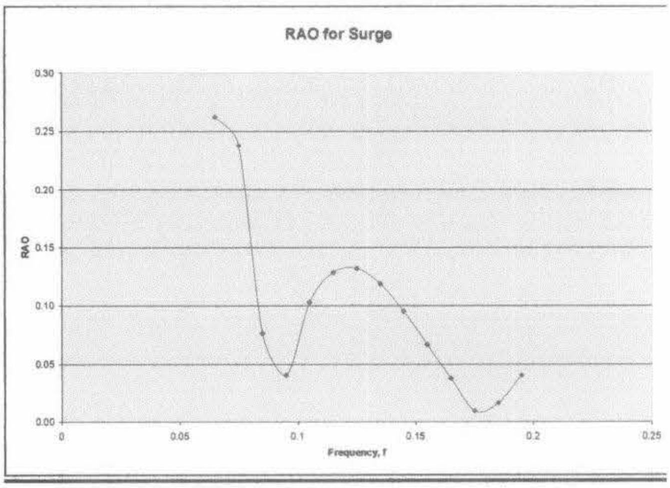


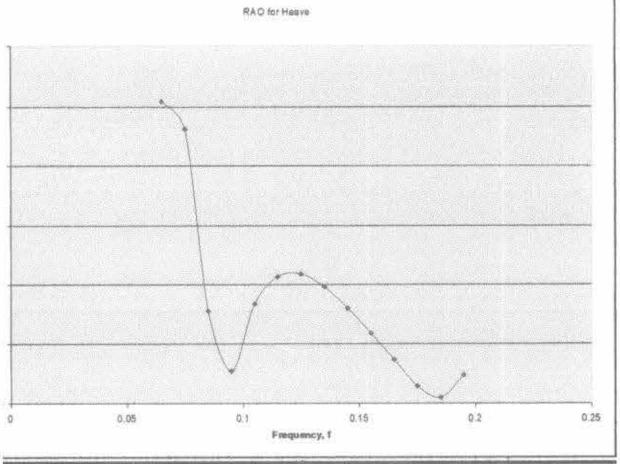
Figure 4.2.4: Random waves models.

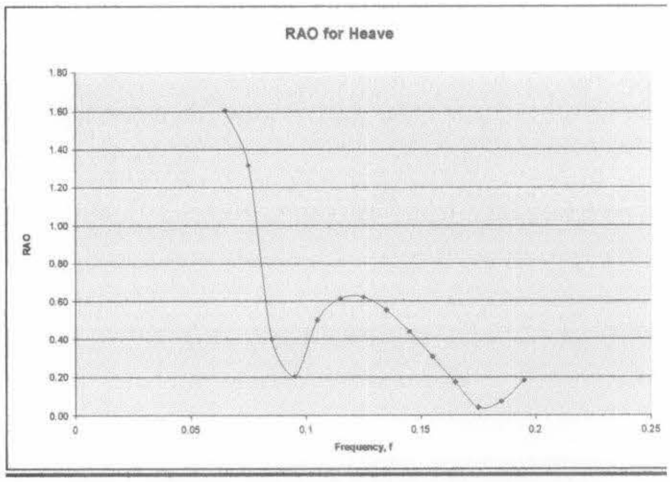
Analytical predictions of the spar motion are achieved using time-domain, Motion-Response Spectrum. From the Motion-Response Spectrum we can obtain the RAO graph that shows the displacement of the Neptune Classic spar due to the random waves profile at certain time. In conducting the Motion-Response Spectrum we need to obtain the stiffness for all responses of the Neptune spar. In this case, the spar is assumed to have general natural period shows in table 4.1.5 and through this the stiffness for every responses can be determine.

Neptune Classic Spar | **Hoover-Diana Classic Spar**









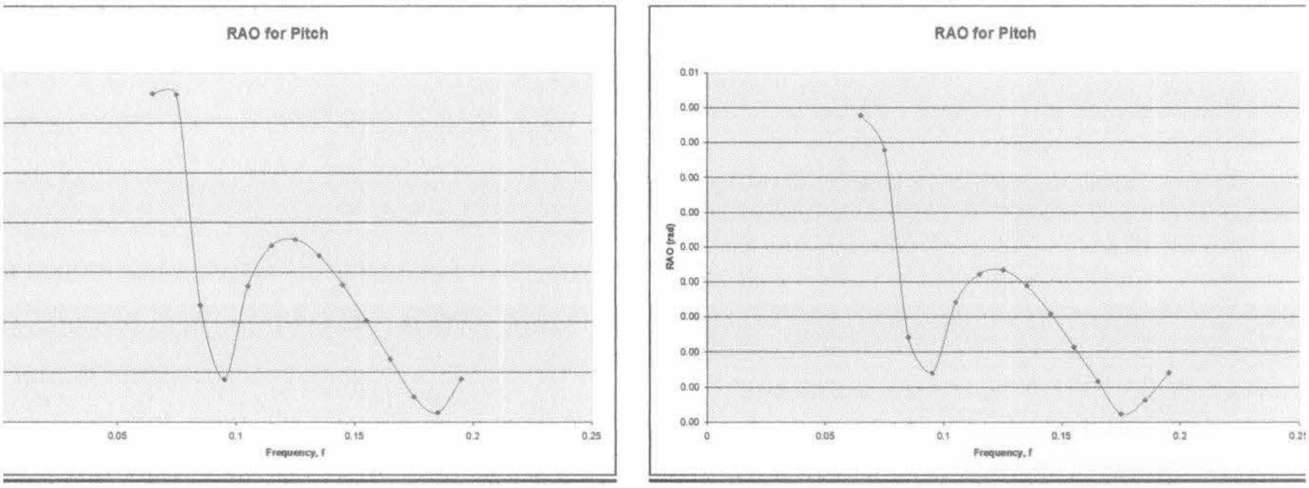
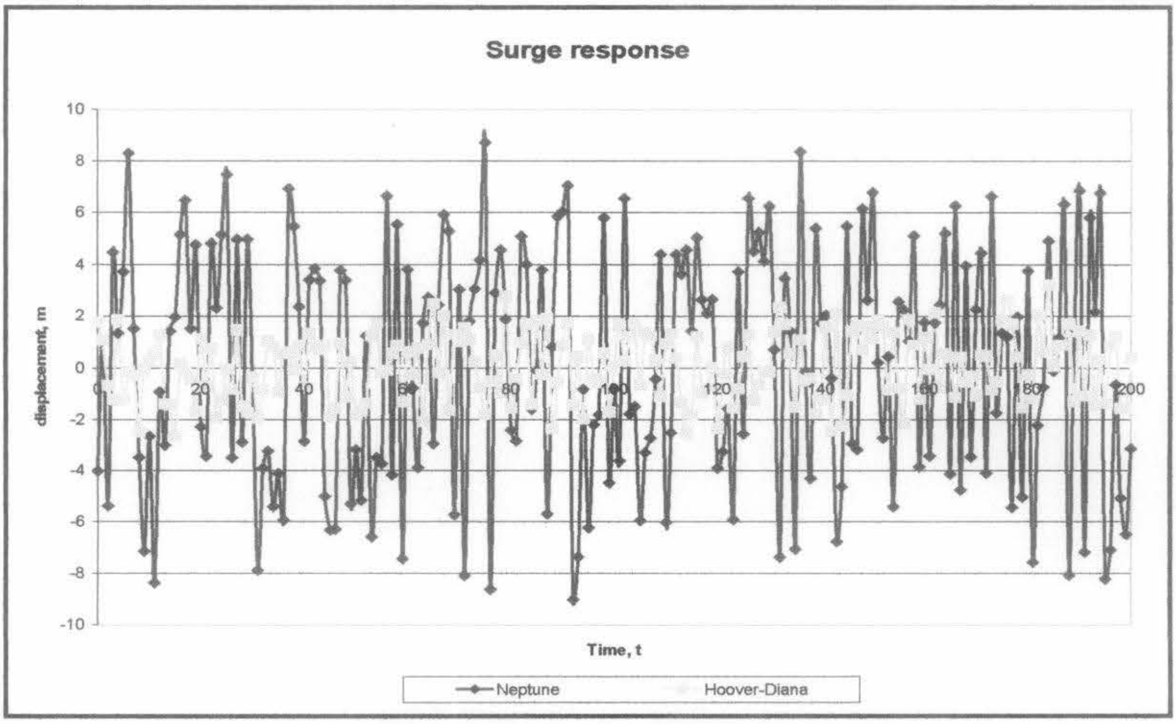
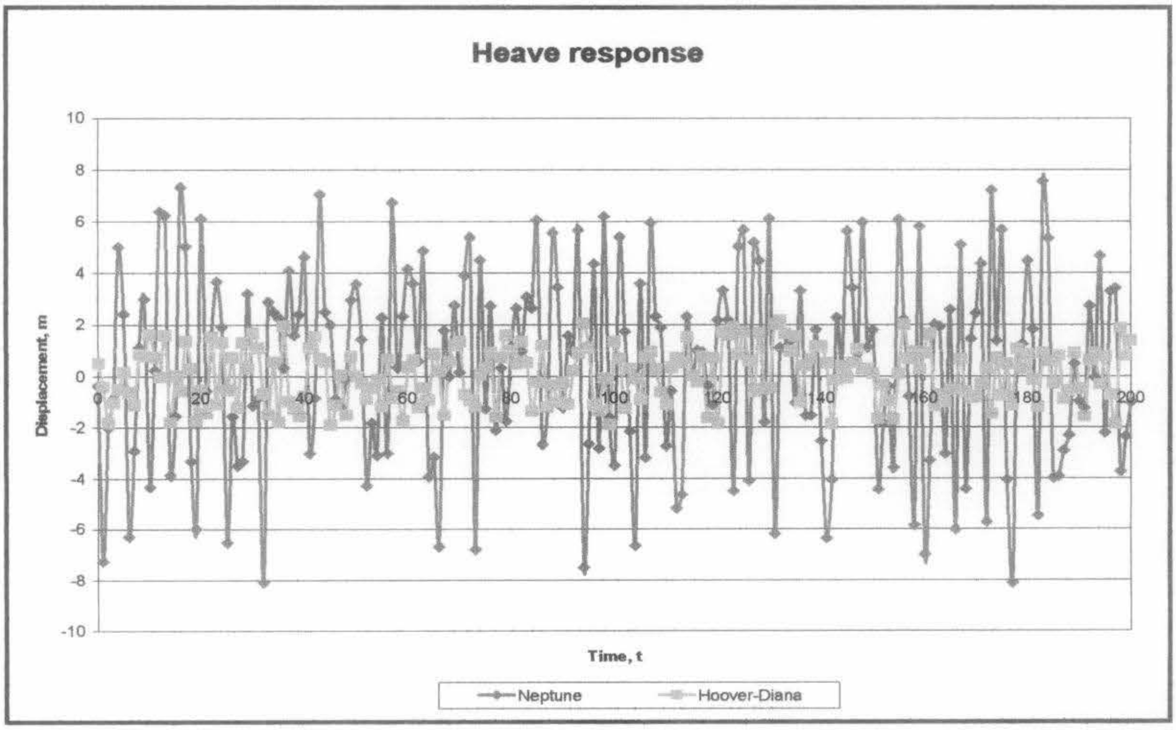


Figure 4.2.5: RAO graph for Neptune and Hoover-Diana Classic Spar

	Maximum RAO		
	Surge	Heave	Pitch
Neptune Classic Spar	0.832	0.779	0.832
Hoover-Diana Classic Spar	0.262	1.604	0.004

Table 4.2.1: Maximum RAO


Surge response
10
8
6
4
2
0
-2
-4
-6
-8
-10
displacement, m
0
20
40
60
80
100
120
140
160
180
200
Time, t
Neptune
Hoover-Diana


Heave response
10
8
6
4
2
0
-2
-4
-6
-8
-10
Displacement, m
0
20
40
60
80
100
120
140
160
180
200
Time, t
Neptune
Hoover-Diana

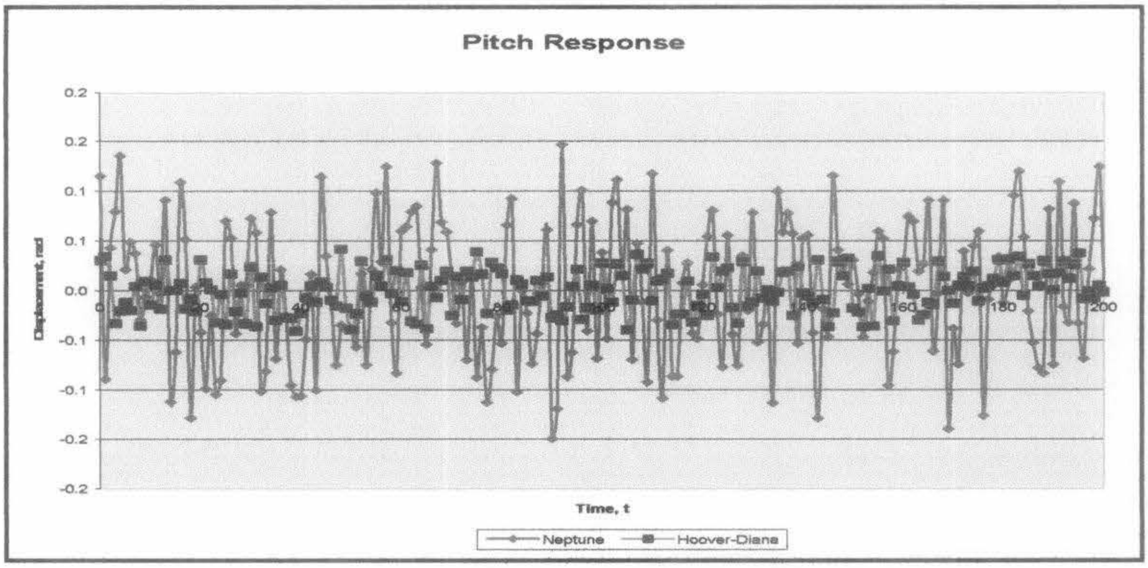


Figure 4.2.6: Maximum Displacement subjected to time

	Maximum displacement (m)		Maximum Displacement (rad)
	Surge	Heave	Pitch
Neptune Classic Spar	-9.0188	-8.111	-0.1496
Hoover-Diana Classic Spar	3.2118	2.163	0.0417

Table 4.2.2: Maximum Displacement for Neptune and Hoover-Diana Classic Spar

The responses graphs above represent how the Neptune and Hoover-Diana Classic spars responses due to the environmental load subjected to time. From the graph the displacement of the structure can be obtain. Prediction of how a structure will response due to the environmental load is needed to be analyzed because to determine either the structure is compatible to be installed at the location or not. From the analysis conducted both spars is stable to be installed at such environmental load field. While the maximum displacement for both spars need to be obtain so the raisers can be design at optimum length and any other characteristic suit with the behavior of the spar such as flexible riser need to be used in the design or other types of risers. In certain cases the spar will be connected to FPSO (Floating Production Storage and Offloading) for crude storage, so a pipeline system will connect the spar and FPSO. To design the pipeline we need to know the maximum displacement of the spar and the behavior of the spar response to the environmental loads.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

1) This analysis of responses of Neptune and Hoover-Diana Classic Spar subjected to random waves gave the spar responses. The responses showed that it is extremely stable structure with acceptable values in Surge, Heave and Pitch.

2) The maximum Surge response for Neptune Classic Spar is 9.0188 m, and 3.2118 m for Hoover-Diana Classic spar. Maximum Heave responses for Neptune and Hoover-Diana classic spar are 8.111 m and 2.163 m. For Pitch responses 0.1496 rad for Neptune classic spar and 0.0417 rad for Hoover-Diana classic spar. These were all within permissible limit.

3) The analyses also proved that spar have a bright future for deepwater exploration. It is necessary to determine the response with various load combination to get more performance criteria.

4) The project has given a better understanding about the Deepwater Technology that needs to be explored and applied in Malaysia.

5) To improve the project, a model studies on a classic spar that can be tested in a wave flume and compare the theoretical result values.

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2. S.K. Chakrabarti *"Hydrodynamics of Offshore Structure"*
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Appendix A: Morison Equation

y	s = y+d	θ (kx-ωt)	sin θ	cos θ	ks	cosh ks	sinh ks	particle velocities (m/s)		particle acceleration (m/s²)	
								horizontal (u)	vertical (v)	horizontal (u')	vertical (v')
0	982.98	-0.5454	-0.5188	0.8549	35.78047	1.731E+15	1.731E+15	1.14442	-0.69450	-0.40404	-0.66579
-1	981.98	-0.5454	-0.5188	0.8549	35.74407	1.669E+15	1.669E+15	1.10351	-0.66967	-0.38960	-0.64200
-2	980.98	-0.5454	-0.5188	0.8549	35.70767	1.609E+15	1.609E+15	1.06406	-0.64573	-0.37567	-0.61905
-3	979.98	-0.5454	-0.5188	0.8549	35.67127	1.552E+15	1.552E+15	1.02603	-0.62265	-0.36224	-0.59692
-4	978.98	-0.5454	-0.5188	0.8549	35.63487	1.496E+15	1.496E+15	0.98935	-0.60039	-0.34929	-0.57558
-5	977.98	-0.5454	-0.5188	0.8549	35.59847	1.443E+15	1.443E+15	0.95399	-0.57893	-0.33681	-0.55501
-6	976.98	-0.5454	-0.5188	0.8549	35.56207	1.391E+15	1.391E+15	0.91989	-0.55824	-0.32477	-0.53517
-7	975.98	-0.5454	-0.5188	0.8549	35.52567	1.341E+15	1.341E+15	0.88701	-0.53828	-0.31316	-0.51604
-8	974.98	-0.5454	-0.5188	0.8549	35.48927	1.293E+15	1.293E+15	0.85530	-0.51904	-0.30197	-0.49759
-9	973.98	-0.5454	-0.5188	0.8549	35.45287	1.247E+15	1.247E+15	0.82473	-0.50049	-0.29117	-0.47981
-10	972.98	-0.5454	-0.5188	0.8549	35.41647	1.203E+15	1.203E+15	0.79525	-0.48260	-0.28076	-0.46265
-11	971.98	-0.5454	-0.5188	0.8549	35.38007	1.160E+15	1.160E+15	0.76682	-0.46535	-0.27073	-0.44612
-12	970.98	-0.5454	-0.5188	0.8549	35.34367	1.118E+15	1.118E+15	0.73941	-0.44871	-0.26105	-0.43017
-13	969.98	-0.5454	-0.5188	0.8549	35.30727	1.078E+15	1.078E+15	0.71298	-0.43267	-0.25172	-0.41479
-14	968.98	-0.5454	-0.5188	0.8549	35.27087	1.040E+15	1.040E+15	0.68749	-0.41721	-0.24272	-0.39997
-15	967.98	-0.5454	-0.5188	0.8549	35.23447	1.003E+15	1.003E+15	0.66292	-0.40229	-0.23405	-0.38567
-16	966.98	-0.5454	-0.5188	0.8549	35.19807	9.667E+14	9.667E+14	0.63922	-0.38791	-0.22568	-0.37188
-17	965.98	-0.5454	-0.5188	0.8549	35.16167	9.322E+14	9.322E+14	0.61637	-0.37405	-0.21761	-0.35859
-18	964.98	-0.5454	-0.5188	0.8549	35.12527	8.988E+14	8.988E+14	0.59434	-0.36068	-0.20983	-0.34577
-19	963.98	-0.5454	-0.5188	0.8549	35.08887	8.667E+14	8.667E+14	0.57310	-0.34779	-0.20233	-0.33341
-20	962.98	-0.5454	-0.5188	0.8549	35.05247	8.357E+14	8.357E+14	0.55261	-0.33535	-0.19510	-0.32149
-21	961.98	-0.5454	-0.5188	0.8549	35.01607	8.059E+14	8.059E+14	0.53286	-0.32337	-0.18813	-0.31000
-22	960.98	-0.5454	-0.5188	0.8549	34.97967	7.770E+14	7.770E+14	0.51381	-0.31181	-0.18140	-0.29892
-23	959.98	-0.5454	-0.5188	0.8549	34.94327	7.493E+14	7.493E+14	0.49544	-0.30066	-0.17492	-0.28824
-24	958.98	-0.5454	-0.5188	0.8549	34.90687	7.225E+14	7.225E+14	0.47773	-0.28991	-0.16867	-0.27793
-25	957.98	-0.5454	-0.5188	0.8549	34.87047	6.967E+14	6.967E+14	0.46066	-0.27955	-0.16264	-0.26800
-26	956.98	-0.5454	-0.5188	0.8549	34.83407	6.718E+14	6.718E+14	0.44419	-0.26956	-0.15682	-0.25842
-27	955.98	-0.5454	-0.5188	0.8549	34.79767	6.477E+14	6.477E+14	0.42831	-0.25992	-0.15122	-0.24918
-28	954.98	-0.5454	-0.5188	0.8549	34.76127	6.246E+14	6.246E+14	0.41300	-0.25063	-0.14581	-0.24027
-29	953.98	-0.5454	-0.5188	0.8549	34.72487	6.023E+14	6.023E+14	0.39824	-0.24167	-0.14060	-0.23169
-30	952.98	-0.5454	-0.5188	0.8549	34.68847	5.807E+14	5.807E+14	0.38400	-0.23303	-0.13557	-0.22340
-31	951.98	-0.5454	-0.5188	0.8549	34.65207	5.600E+14	5.600E+14	0.37028	-0.22470	-0.13073	-0.21542

-32	950.98	-0.5454	-0.5188	0.8549	34.61567	5.400E+14	5.400E+14	0.35704	-0.21667	-0.12605	-0.20772
-33	949.98	-0.5454	-0.5188	0.8549	34.57927	5.207E+14	5.207E+14	0.34428	-0.20893	-0.12155	-0.20029
-34	948.98	-0.5454	-0.5188	0.8549	34.54287	5.021E+14	5.021E+14	0.33197	-0.20146	-0.11720	-0.19313
-35	947.98	-0.5454	-0.5188	0.8549	34.50647	4.841E+14	4.841E+14	0.32011	-0.19426	-0.11301	-0.18623
-36	946.98	-0.5454	-0.5188	0.8549	34.47007	4.668E+14	4.668E+14	0.30866	-0.18731	-0.10897	-0.17957
-37	945.98	-0.5454	-0.5188	0.8549	34.43367	4.501E+14	4.501E+14	0.29763	-0.18062	-0.10508	-0.17315
-38	944.98	-0.5454	-0.5188	0.8549	34.39727	4.340E+14	4.340E+14	0.28699	-0.17416	-0.10132	-0.16696
-39	943.98	-0.5454	-0.5188	0.8549	34.36087	4.185E+14	4.185E+14	0.27673	-0.16794	-0.09770	-0.16100
-40	942.98	-0.5454	-0.5188	0.8549	34.32447	4.036E+14	4.036E+14	0.26684	-0.16193	-0.09421	-0.15524
-41	941.98	-0.5454	-0.5188	0.8549	34.28807	3.891E+14	3.891E+14	0.25730	-0.15615	-0.09084	-0.14969
-42	940.98	-0.5454	-0.5188	0.8549	34.25167	3.752E+14	3.752E+14	0.24810	-0.15056	-0.08759	-0.14434
-43	939.98	-0.5454	-0.5188	0.8549	34.21527	3.618E+14	3.618E+14	0.23924	-0.14518	-0.08446	-0.13918
-44	938.98	-0.5454	-0.5188	0.8549	34.17887	3.489E+14	3.489E+14	0.23068	-0.13999	-0.08144	-0.13421
-45	937.98	-0.5454	-0.5188	0.8549	34.14247	3.364E+14	3.364E+14	0.22244	-0.13499	-0.07853	-0.12941
-46	936.98	-0.5454	-0.5188	0.8549	34.10607	3.244E+14	3.244E+14	0.21449	-0.13016	-0.07573	-0.12478
-47	935.98	-0.5454	-0.5188	0.8549	34.06967	3.128E+14	3.128E+14	0.20682	-0.12551	-0.07302	-0.12032
-48	934.98	-0.5454	-0.5188	0.8549	34.03327	3.016E+14	3.016E+14	0.19943	-0.12102	-0.07041	-0.11602
-49	933.98	-0.5454	-0.5188	0.8549	33.99687	2.908E+14	2.908E+14	0.19230	-0.11670	-0.06789	-0.11187
-50	932.98	-0.5454	-0.5188	0.8549	33.96047	2.804E+14	2.804E+14	0.18543	-0.11253	-0.06546	-0.10788
-51	931.98	-0.5454	-0.5188	0.8549	33.92407	2.704E+14	2.704E+14	0.17880	-0.10850	-0.06312	-0.10402
-52	930.98	-0.5454	-0.5188	0.8549	33.88767	2.607E+14	2.607E+14	0.17241	-0.10463	-0.06087	-0.10030
-53	929.98	-0.5454	-0.5188	0.8549	33.85127	2.514E+14	2.514E+14	0.16624	-0.10089	-0.05869	-0.09672
-54	928.98	-0.5454	-0.5188	0.8549	33.81487	2.424E+14	2.424E+14	0.16030	-0.09728	-0.05659	-0.09326
-55	927.98	-0.5454	-0.5188	0.8549	33.77847	2.338E+14	2.338E+14	0.15457	-0.09380	-0.05457	-0.08993
-56	926.98	-0.5454	-0.5188	0.8549	33.74207	2.254E+14	2.254E+14	0.14905	-0.09045	-0.05262	-0.08671
-57	925.98	-0.5454	-0.5188	0.8549	33.70567	2.173E+14	2.173E+14	0.14372	-0.08722	-0.05074	-0.08361
-58	924.98	-0.5454	-0.5188	0.8549	33.66927	2.096E+14	2.096E+14	0.13858	-0.08410	-0.04893	-0.08062
-59	923.98	-0.5454	-0.5188	0.8549	33.63287	2.021E+14	2.021E+14	0.13363	-0.08109	-0.04718	-0.07774
-60	922.98	-0.5454	-0.5188	0.8549	33.59647	1.949E+14	1.949E+14	0.12885	-0.07819	-0.04549	-0.07496
-61	921.98	-0.5454	-0.5188	0.8549	33.56007	1.879E+14	1.879E+14	0.12424	-0.07540	-0.04386	-0.07228
-62	920.98	-0.5454	-0.5188	0.8549	33.52367	1.812E+14	1.812E+14	0.11980	-0.07270	-0.04230	-0.06970
-63	919.98	-0.5454	-0.5188	0.8549	33.48727	1.747E+14	1.747E+14	0.11552	-0.07010	-0.04079	-0.06721
-64	918.98	-0.5454	-0.5188	0.8549	33.45087	1.685E+14	1.685E+14	0.11139	-0.06760	-0.03933	-0.06480
-65	917.98	-0.5454	-0.5188	0.8549	33.41447	1.624E+14	1.624E+14	0.10741	-0.06518	-0.03792	-0.06249

-66	916.98	-0.5454	-0.5188	0.8549	33.37807	1.566E+14	1.566E+14	0.10357	-0.06285	-0.03657	-0.06025
-67	915.98	-0.5454	-0.5188	0.8549	33.34167	1.510E+14	1.510E+14	0.09987	-0.06061	-0.03526	-0.05810
-68	914.98	-0.5454	-0.5188	0.8549	33.30527	1.456E+14	1.456E+14	0.09630	-0.05844	-0.03400	-0.05602
-69	913.98	-0.5454	-0.5188	0.8549	33.26887	1.404E+14	1.404E+14	0.09286	-0.05635	-0.03278	-0.05402
-70	912.98	-0.5454	-0.5188	0.8549	33.23247	1.354E+14	1.354E+14	0.08954	-0.05434	-0.03161	-0.05209
-71	911.98	-0.5454	-0.5188	0.8549	33.19607	1.306E+14	1.306E+14	0.08634	-0.05239	-0.03048	-0.05023
-72	910.98	-0.5454	-0.5188	0.8549	33.15967	1.259E+14	1.259E+14	0.08325	-0.05052	-0.02939	-0.04843
-73	909.98	-0.5454	-0.5188	0.8549	33.12327	1.214E+14	1.214E+14	0.08027	-0.04871	-0.02834	-0.04670
-74	908.98	-0.5454	-0.5188	0.8549	33.08687	1.171E+14	1.171E+14	0.07741	-0.04697	-0.02733	-0.04503
-75	907.98	-0.5454	-0.5188	0.8549	33.05047	1.129E+14	1.129E+14	0.07464	-0.04529	-0.02635	-0.04342
-76	906.98	-0.5454	-0.5188	0.8549	33.01407	1.088E+14	1.088E+14	0.07197	-0.04368	-0.02541	-0.04187
-77	905.98	-0.5454	-0.5188	0.8549	32.97767	1.050E+14	1.050E+14	0.06940	-0.04211	-0.02450	-0.04037
-78	904.98	-0.5454	-0.5188	0.8549	32.94127	1.012E+14	1.012E+14	0.06692	-0.04061	-0.02363	-0.03893
-79	903.98	-0.5454	-0.5188	0.8549	32.90487	9.758E+13	9.758E+13	0.06452	-0.03916	-0.02278	-0.03754
-80	902.98	-0.5454	-0.5188	0.8549	32.86847	9.409E+13	9.409E+13	0.06222	-0.03776	-0.02197	-0.03620
-81	901.98	-0.5454	-0.5188	0.8549	32.83207	9.073E+13	9.073E+13	0.05999	-0.03641	-0.02118	-0.03490
-82	900.98	-0.5454	-0.5188	0.8549	32.79567	8.749E+13	8.749E+13	0.05785	-0.03511	-0.02042	-0.03366
-83	899.98	-0.5454	-0.5188	0.8549	32.75927	8.436E+13	8.436E+13	0.05578	-0.03385	-0.01969	-0.03245
-84	898.98	-0.5454	-0.5188	0.8549	32.72287	8.135E+13	8.135E+13	0.05379	-0.03264	-0.01899	-0.03129
-85	897.98	-0.5454	-0.5188	0.8549	32.68647	7.844E+13	7.844E+13	0.05187	-0.03147	-0.01831	-0.03017
-86	896.98	-0.5454	-0.5188	0.8549	32.65007	7.563E+13	7.563E+13	0.05001	-0.03035	-0.01766	-0.02910
-87	895.98	-0.5454	-0.5188	0.8549	32.61367	7.293E+13	7.293E+13	0.04822	-0.02926	-0.01703	-0.02806
-88	894.98	-0.5454	-0.5188	0.8549	32.57727	7.032E+13	7.032E+13	0.04650	-0.02822	-0.01642	-0.02705
-89	893.98	-0.5454	-0.5188	0.8549	32.54087	6.781E+13	6.781E+13	0.04484	-0.02721	-0.01583	-0.02609
-90	892.98	-0.5454	-0.5188	0.8549	32.50447	6.539E+13	6.539E+13	0.04324	-0.02624	-0.01526	-0.02515
-91	891.98	-0.5454	-0.5188	0.8549	32.46807	6.305E+13	6.305E+13	0.04169	-0.02530	-0.01472	-0.02425
-92	890.98	-0.5454	-0.5188	0.8549	32.43167	6.079E+13	6.079E+13	0.04020	-0.02440	-0.01419	-0.02339
-93	889.98	-0.5454	-0.5188	0.8549	32.39527	5.862E+13	5.862E+13	0.03876	-0.02352	-0.01369	-0.02255
-94	888.98	-0.5454	-0.5188	0.8549	32.35887	5.653E+13	5.653E+13	0.03738	-0.02268	-0.01320	-0.02174
-95	887.98	-0.5454	-0.5188	0.8549	32.32247	5.451E+13	5.451E+13	0.03604	-0.02187	-0.01272	-0.02097
-96	886.98	-0.5454	-0.5188	0.8549	32.28607	5.256E+13	5.256E+13	0.03475	-0.02109	-0.01227	-0.02022
-97	885.98	-0.5454	-0.5188	0.8549	32.24967	5.068E+13	5.068E+13	0.03351	-0.02034	-0.01183	-0.01950
-98	884.98	-0.5454	-0.5188	0.8549	32.21327	4.887E+13	4.887E+13	0.03231	-0.01961	-0.01141	-0.01880
-99	883.98	-0.5454	-0.5188	0.8549	32.17687	4.712E+13	4.712E+13	0.03116	-0.01891	-0.01100	-0.01813

-100	882.98	-0.5454	-0.5188	0.8549	32.14047	4.544E+13	4.544E+13	0.03004	-0.01823	-0.01061	-0.01748
-101	881.98	-0.5454	-0.5188	0.8549	32.10407	4.381E+13	4.381E+13	0.02897	-0.01758	-0.01023	-0.01685
-102	880.98	-0.5454	-0.5188	0.8549	32.06767	4.225E+13	4.225E+13	0.02793	-0.01695	-0.00986	-0.01625
-103	879.98	-0.5454	-0.5188	0.8549	32.03127	4.074E+13	4.074E+13	0.02694	-0.01635	-0.00951	-0.01567
-104	878.98	-0.5454	-0.5188	0.8549	31.99487	3.928E+13	3.928E+13	0.02597	-0.01576	-0.00917	-0.01511
-105	877.98	-0.5454	-0.5188	0.8549	31.95847	3.788E+13	3.788E+13	0.02504	-0.01520	-0.00884	-0.01457
-106	876.98	-0.5454	-0.5188	0.8549	31.92207	3.652E+13	3.652E+13	0.02415	-0.01466	-0.00853	-0.01405
-107	875.98	-0.5454	-0.5188	0.8549	31.88567	3.522E+13	3.522E+13	0.02329	-0.01413	-0.00822	-0.01355
-108	874.98	-0.5454	-0.5188	0.8549	31.84927	3.396E+13	3.396E+13	0.02245	-0.01363	-0.00793	-0.01306
-109	873.98	-0.5454	-0.5188	0.8549	31.81287	3.274E+13	3.274E+13	0.02165	-0.01314	-0.00764	-0.01260
-110	872.98	-0.5454	-0.5188	0.8549	31.77647	3.157E+13	3.157E+13	0.02088	-0.01267	-0.00737	-0.01215
-111	871.98	-0.5454	-0.5188	0.8549	31.74007	3.044E+13	3.044E+13	0.02013	-0.01222	-0.00711	-0.01171
-112	870.98	-0.5454	-0.5188	0.8549	31.70367	2.936E+13	2.936E+13	0.01941	-0.01178	-0.00685	-0.01129
-113	869.98	-0.5454	-0.5188	0.8549	31.66727	2.831E+13	2.831E+13	0.01872	-0.01136	-0.00661	-0.01089
-114	868.98	-0.5454	-0.5188	0.8549	31.63087	2.730E+13	2.730E+13	0.01805	-0.01095	-0.00637	-0.01050
-115	867.98	-0.5454	-0.5188	0.8549	31.59447	2.632E+13	2.632E+13	0.01740	-0.01056	-0.00614	-0.01012
-116	866.98	-0.5454	-0.5188	0.8549	31.55807	2.538E+13	2.538E+13	0.01678	-0.01018	-0.00592	-0.00976
-117	865.98	-0.5454	-0.5188	0.8549	31.52167	2.447E+13	2.447E+13	0.01618	-0.00982	-0.00571	-0.00941
-118	864.98	-0.5454	-0.5188	0.8549	31.48527	2.360E+13	2.360E+13	0.01560	-0.00947	-0.00551	-0.00908
-119	863.98	-0.5454	-0.5188	0.8549	31.44887	2.275E+13	2.275E+13	0.01505	-0.00913	-0.00531	-0.00875
-120	862.98	-0.5454	-0.5188	0.8549	31.41247	2.194E+13	2.194E+13	0.01451	-0.00880	-0.00512	-0.00844
-121	861.98	-0.5454	-0.5188	0.8549	31.37607	2.116E+13	2.116E+13	0.01399	-0.00849	-0.00494	-0.00814
-122	860.98	-0.5454	-0.5188	0.8549	31.33967	2.040E+13	2.040E+13	0.01349	-0.00819	-0.00476	-0.00785
-123	859.98	-0.5454	-0.5188	0.8549	31.30327	1.967E+13	1.967E+13	0.01301	-0.00789	-0.00459	-0.00757
-124	858.98	-0.5454	-0.5188	0.8549	31.26687	1.897E+13	1.897E+13	0.01254	-0.00761	-0.00443	-0.00730
-125	857.98	-0.5454	-0.5188	0.8549	31.23047	1.829E+13	1.829E+13	0.01209	-0.00734	-0.00427	-0.00704
-126	856.98	-0.5454	-0.5188	0.8549	31.19407	1.764E+13	1.764E+13	0.01166	-0.00708	-0.00412	-0.00678
-127	855.98	-0.5454	-0.5188	0.8549	31.15767	1.700E+13	1.700E+13	0.01124	-0.00682	-0.00397	-0.00654
-128	854.98	-0.5454	-0.5188	0.8549	31.12127	1.640E+13	1.640E+13	0.01084	-0.00658	-0.00383	-0.00631
-129	853.98	-0.5454	-0.5188	0.8549	31.08487	1.581E+13	1.581E+13	0.01045	-0.00634	-0.00369	-0.00608
-130	852.98	-0.5454	-0.5188	0.8549	31.04847	1.525E+13	1.525E+13	0.01008	-0.00612	-0.00356	-0.00586
-131	851.98	-0.5454	-0.5188	0.8549	31.01207	1.470E+13	1.470E+13	0.00972	-0.00590	-0.00343	-0.00566
-132	850.98	-0.5454	-0.5188	0.8549	30.97567	1.418E+13	1.418E+13	0.00937	-0.00569	-0.00331	-0.00545
-133	849.98	-0.5454	-0.5188	0.8549	30.93927	1.367E+13	1.367E+13	0.00904	-0.00548	-0.00319	-0.00526

-134	848.98	-0.5454	-0.5188	0.8549	30.90287	1.318E+13	1.318E+13	0.00872	-0.00529	-0.00308	-0.00507
-135	847.98	-0.5454	-0.5188	0.8549	30.86647	1.271E+13	1.271E+13	0.00840	-0.00510	-0.00297	-0.00489
-136	846.98	-0.5454	-0.5188	0.8549	30.83007	1.225E+13	1.225E+13	0.00810	-0.00492	-0.00286	-0.00471
-137	845.98	-0.5454	-0.5188	0.8549	30.79367	1.182E+13	1.182E+13	0.00781	-0.00474	-0.00276	-0.00455
-138	844.98	-0.5454	-0.5188	0.8549	30.75727	1.139E+13	1.139E+13	0.00753	-0.00457	-0.00266	-0.00438
-139	843.98	-0.5454	-0.5188	0.8549	30.72087	1.099E+13	1.099E+13	0.00726	-0.00441	-0.00256	-0.00423
-140	842.98	-0.5454	-0.5188	0.8549	30.68447	1.059E+13	1.059E+13	0.00701	-0.00425	-0.00247	-0.00408
-141	841.98	-0.5454	-0.5188	0.8549	30.64807	1.022E+13	1.022E+13	0.00675	-0.00410	-0.00238	-0.00393
-142	840.98	-0.5454	-0.5188	0.8549	30.61167	9.850E+12	9.850E+12	0.00651	-0.00395	-0.00230	-0.00379
-143	839.98	-0.5454	-0.5188	0.8549	30.57527	9.498E+12	9.498E+12	0.00628	-0.00381	-0.00222	-0.00365
-144	838.98	-0.5454	-0.5188	0.8549	30.53887	9.159E+12	9.159E+12	0.00606	-0.00368	-0.00214	-0.00352
-145	837.98	-0.5454	-0.5188	0.8549	30.50247	8.831E+12	8.831E+12	0.00584	-0.00354	-0.00206	-0.00340
-146	836.98	-0.5454	-0.5188	0.8549	30.46607	8.516E+12	8.516E+12	0.00563	-0.00342	-0.00199	-0.00328
-147	835.98	-0.5454	-0.5188	0.8549	30.42967	8.211E+12	8.211E+12	0.00543	-0.00329	-0.00192	-0.00316
-148	834.98	-0.5454	-0.5188	0.8549	30.39327	7.918E+12	7.918E+12	0.00524	-0.00318	-0.00185	-0.00305
-149	833.98	-0.5454	-0.5188	0.8549	30.35687	7.635E+12	7.635E+12	0.00505	-0.00306	-0.00178	-0.00294
-150	832.98	-0.5454	-0.5188	0.8549	30.32047	7.362E+12	7.362E+12	0.00487	-0.00295	-0.00172	-0.00283
-151	831.98	-0.5454	-0.5188	0.8549	30.28407	7.099E+12	7.099E+12	0.00469	-0.00285	-0.00166	-0.00273
-152	830.98	-0.5454	-0.5188	0.8549	30.24767	6.845E+12	6.845E+12	0.00453	-0.00275	-0.00160	-0.00263
-153	829.98	-0.5454	-0.5188	0.8549	30.21127	6.600E+12	6.600E+12	0.00436	-0.00265	-0.00154	-0.00254
-154	828.98	-0.5454	-0.5188	0.8549	30.17487	6.364E+12	6.364E+12	0.00421	-0.00255	-0.00149	-0.00245
-155	827.98	-0.5454	-0.5188	0.8549	30.13847	6.137E+12	6.137E+12	0.00406	-0.00246	-0.00143	-0.00236
-156	826.98	-0.5454	-0.5188	0.8549	30.10207	5.917E+12	5.917E+12	0.00391	-0.00237	-0.00138	-0.00228
-157	825.98	-0.5454	-0.5188	0.8549	30.06567	5.706E+12	5.706E+12	0.00377	-0.00229	-0.00133	-0.00219
-158	824.98	-0.5454	-0.5188	0.8549	30.02927	5.502E+12	5.502E+12	0.00364	-0.00221	-0.00128	-0.00212
-159	823.98	-0.5454	-0.5188	0.8549	29.99287	5.305E+12	5.305E+12	0.00351	-0.00213	-0.00124	-0.00204
-160	822.98	-0.5454	-0.5188	0.8549	29.95647	5.116E+12	5.116E+12	0.00338	-0.00205	-0.00119	-0.00197
-161	821.98	-0.5454	-0.5188	0.8549	29.92007	4.933E+12	4.933E+12	0.00326	-0.00198	-0.00115	-0.00190
-162	820.98	-0.5454	-0.5188	0.8549	29.88367	4.756E+12	4.756E+12	0.00315	-0.00191	-0.00111	-0.00183
-163	819.98	-0.5454	-0.5188	0.8549	29.84727	4.586E+12	4.586E+12	0.00303	-0.00184	-0.00107	-0.00176
-164	818.98	-0.5454	-0.5188	0.8549	29.81087	4.422E+12	4.422E+12	0.00292	-0.00177	-0.00103	-0.00170
-165	817.98	-0.5454	-0.5188	0.8549	29.77447	4.264E+12	4.264E+12	0.00282	-0.00171	-0.00100	-0.00164
-166	816.98	-0.5454	-0.5188	0.8549	29.73807	4.112E+12	4.112E+12	0.00272	-0.00165	-0.00096	-0.00158
-167	815.98	-0.5454	-0.5188	0.8549	29.70167	3.965E+12	3.965E+12	0.00262	-0.00159	-0.00093	-0.00153

-168	814.98	-0.5454	-0.5188	0.8549	29.66527	3.823E+12	3.823E+12	0.00253	-0.00153	-0.00089	-0.00147
-169	813.98	-0.5454	-0.5188	0.8549	29.62887	3.687E+12	3.687E+12	0.00244	-0.00148	-0.00086	-0.00142
-170	812.98	-0.5454	-0.5188	0.8549	29.59247	3.555E+12	3.555E+12	0.00235	-0.00143	-0.00083	-0.00137
-171	811.98	-0.5454	-0.5188	0.8549	29.55607	3.428E+12	3.428E+12	0.00227	-0.00138	-0.00080	-0.00132
-172	810.98	-0.5454	-0.5188	0.8549	29.51967	3.305E+12	3.305E+12	0.00219	-0.00133	-0.00077	-0.00127
-173	809.98	-0.5454	-0.5188	0.8549	29.48327	3.187E+12	3.187E+12	0.00211	-0.00128	-0.00074	-0.00123
-174	808.98	-0.5454	-0.5188	0.8549	29.44687	3.073E+12	3.073E+12	0.00203	-0.00123	-0.00072	-0.00118
-175	807.98	-0.5454	-0.5188	0.8549	29.41047	2.963E+12	2.963E+12	0.00196	-0.00119	-0.00069	-0.00114
-176	806.98	-0.5454	-0.5188	0.8549	29.37407	2.857E+12	2.857E+12	0.00189	-0.00115	-0.00067	-0.00110
-177	805.98	-0.5454	-0.5188	0.8549	29.33767	2.755E+12	2.755E+12	0.00182	-0.00111	-0.00064	-0.00106
-178	804.98	-0.5454	-0.5188	0.8549	29.30127	2.657E+12	2.657E+12	0.00176	-0.00107	-0.00062	-0.00102
-179	803.98	-0.5454	-0.5188	0.8549	29.26487	2.562E+12	2.562E+12	0.00169	-0.00103	-0.00060	-0.00099
-180	802.98	-0.5454	-0.5188	0.8549	29.22847	2.470E+12	2.470E+12	0.00163	-0.00099	-0.00058	-0.00095
-181	801.98	-0.5454	-0.5188	0.8549	29.19207	2.382E+12	2.382E+12	0.00157	-0.00096	-0.00056	-0.00092
-182	800.98	-0.5454	-0.5188	0.8549	29.15567	2.297E+12	2.297E+12	0.00152	-0.00092	-0.00054	-0.00088
-183	799.98	-0.5454	-0.5188	0.8549	29.11927	2.215E+12	2.215E+12	0.00146	-0.00089	-0.00052	-0.00085
-184	798.98	-0.5454	-0.5188	0.8549	29.08287	2.136E+12	2.136E+12	0.00141	-0.00086	-0.00050	-0.00082
-185	797.98	-0.5454	-0.5188	0.8549	29.04647	2.059E+12	2.059E+12	0.00136	-0.00083	-0.00048	-0.00079
-186	796.98	-0.5454	-0.5188	0.8549	29.01007	1.986E+12	1.986E+12	0.00131	-0.00080	-0.00046	-0.00076
-187	795.98	-0.5454	-0.5188	0.8549	28.97367	1.915E+12	1.915E+12	0.00127	-0.00077	-0.00045	-0.00074
-188	794.98	-0.5454	-0.5188	0.8549	28.93727	1.846E+12	1.846E+12	0.00122	-0.00074	-0.00043	-0.00071
-189	793.98	-0.5454	-0.5188	0.8549	28.90087	1.780E+12	1.780E+12	0.00118	-0.00071	-0.00042	-0.00068
-190	792.98	-0.5454	-0.5188	0.8549	28.86447	1.717E+12	1.717E+12	0.00114	-0.00069	-0.00040	-0.00066
-191	791.98	-0.5454	-0.5188	0.8549	28.82807	1.655E+12	1.655E+12	0.00109	-0.00066	-0.00039	-0.00064
-192	790.98	-0.5454	-0.5188	0.8549	28.79167	1.596E+12	1.596E+12	0.00106	-0.00064	-0.00037	-0.00061
-193	789.98	-0.5454	-0.5188	0.8549	28.75527	1.539E+12	1.539E+12	0.00102	-0.00062	-0.00036	-0.00059
-193.3	789.68	-0.5454	-0.5188	0.8549	28.74435	1.522E+12	1.522E+12	0.00101	-0.00061	-0.00036	-0.00059

Cxu + Cyv	Ux	Uy	Uz	ω	U'x	U'y	U'z	fx	fy	fz	F	x(m)	Mx (kN.m)
-0.6945	1.1444	0	0	1.1444	-0.4040	0	0	-243.47	0	0	243.47	-89.15	-21705.3
-0.6697	1.1035	0	0	1.1035	-0.3896	0	0	-235.10	0	0	235.10	-88.15	-20724
-0.6457	1.0641	0	0	1.0641	-0.3757	0	0	-227.00	0	0	227.00	-87.15	-19783.4
-0.6227	1.0260	0	0	1.0260	-0.3622	0	0	-219.18	0	0	219.18	-86.15	-18882.1
-0.6004	0.9894	0	0	0.9894	-0.3493	0	0	-211.61	0	0	211.61	-85.15	-18018.6
-0.5789	0.9540	0	0	0.9540	-0.3368	0	0	-204.29	0	0	204.29	-84.15	-17191.4
-0.5582	0.9199	0	0	0.9199	-0.3248	0	0	-197.22	0	0	197.22	-83.15	-16399.1
-0.5383	0.8870	0	0	0.8870	-0.3132	0	0	-190.39	0	0	190.39	-82.15	-15640.4
-0.5190	0.8553	0	0	0.8553	-0.3020	0	0	-183.78	0	0	183.78	-81.15	-14913.9
-0.5005	0.8247	0	0	0.8247	-0.2912	0	0	-177.40	0	0	177.40	-80.15	-14218.5
-0.4826	0.7952	0	0	0.7952	-0.2808	0	0	-171.23	0	0	171.23	-79.15	-13552.8
-0.4653	0.7668	0	0	0.7668	-0.2707	0	0	-165.27	0	0	165.27	-78.15	-12915.8
-0.4487	0.7394	0	0	0.7394	-0.2611	0	0	-159.51	0	0	159.51	-77.15	-12306.3
-0.4327	0.7130	0	0	0.7130	-0.2517	0	0	-153.95	0	0	153.95	-76.15	-11723.2
-0.4172	0.6875	0	0	0.6875	-0.2427	0	0	-148.57	0	0	148.57	-75.15	-11165.4
-0.4023	0.6629	0	0	0.6629	-0.2340	0	0	-143.38	0	0	143.38	-74.15	-10631.9
-0.3879	0.6392	0	0	0.6392	-0.2257	0	0	-138.37	0	0	138.37	-73.15	-10121.7
-0.3740	0.6164	0	0	0.6164	-0.2176	0	0	-133.53	0	0	133.53	-72.15	-9633.99
-0.3607	0.5943	0	0	0.5943	-0.2098	0	0	-128.85	0	0	128.85	-71.15	-9167.73
-0.3478	0.5731	0	0	0.5731	-0.2023	0	0	-124.33	0	0	124.33	-70.15	-8722.07
-0.3354	0.5526	0	0	0.5526	-0.1951	0	0	-119.97	0	0	119.97	-69.15	-8296.17
-0.3234	0.5329	0	0	0.5329	-0.1881	0	0	-115.76	0	0	115.76	-68.15	-7889.22
-0.3118	0.5138	0	0	0.5138	-0.1814	0	0	-111.70	0	0	111.70	-67.15	-7500.43
-0.3007	0.4954	0	0	0.4954	-0.1749	0	0	-107.77	0	0	107.77	-66.15	-7129.05
-0.2899	0.4777	0	0	0.4777	-0.1687	0	0	-103.98	0	0	103.98	-65.15	-6774.36
-0.2796	0.4607	0	0	0.4607	-0.1626	0	0	-100.32	0	0	100.32	-64.15	-6435.66
-0.2696	0.4442	0	0	0.4442	-0.1568	0	0	-96.79	0	0	96.79	-63.15	-6112.28
-0.2599	0.4283	0	0	0.4283	-0.1512	0	0	-93.38	0	0	93.38	-62.15	-5803.57
-0.2506	0.4130	0	0	0.4130	-0.1458	0	0	-90.09	0	0	90.09	-61.15	-5508.93
-0.2417	0.3982	0	0	0.3982	-0.1406	0	0	-86.91	0	0	86.91	-60.15	-5227.74
-0.2330	0.3840	0	0	0.3840	-0.1356	0	0	-83.85	0	0	83.85	-59.15	-4959.45
-0.2247	0.3703	0	0	0.3703	-0.1307	0	0	-80.89	0	0	80.89	-58.15	-4703.5

-0.2167	0.3570	0	0	0.3570	-0.1261	0	0	-78.03	0	0	78.03	-57.15	-4459.37
-0.2089	0.3443	0	0	0.3443	-0.1215	0	0	-75.27	0	0	75.27	-56.15	-4226.54
-0.2015	0.3320	0	0	0.3320	-0.1172	0	0	-72.61	0	0	72.61	-55.15	-4004.54
-0.1943	0.3201	0	0	0.3201	-0.1130	0	0	-70.04	0	0	70.04	-54.15	-3792.89
-0.1873	0.3087	0	0	0.3087	-0.1090	0	0	-67.57	0	0	67.57	-53.15	-3591.16
-0.1806	0.2976	0	0	0.2976	-0.1051	0	0	-65.18	0	0	65.18	-52.15	-3398.9
-0.1742	0.2870	0	0	0.2870	-0.1013	0	0	-62.87	0	0	62.87	-51.15	-3215.71
-0.1679	0.2767	0	0	0.2767	-0.0977	0	0	-60.64	0	0	60.64	-50.15	-3041.19
-0.1619	0.2668	0	0	0.2668	-0.0942	0	0	-58.49	0	0	58.49	-49.15	-2874.96
-0.1561	0.2573	0	0	0.2573	-0.0908	0	0	-56.42	0	0	56.42	-48.15	-2716.66
-0.1506	0.2481	0	0	0.2481	-0.0876	0	0	-54.42	0	0	54.42	-47.15	-2565.94
-0.1452	0.2392	0	0	0.2392	-0.0845	0	0	-52.49	0	0	52.49	-46.15	-2422.47
-0.1400	0.2307	0	0	0.2307	-0.0814	0	0	-50.63	0	0	50.63	-45.15	-2285.92
-0.1350	0.2224	0	0	0.2224	-0.0785	0	0	-48.83	0	0	48.83	-44.15	-2155.98
-0.1302	0.2145	0	0	0.2145	-0.0757	0	0	-47.10	0	0	47.10	-43.15	-2032.37
-0.1255	0.2068	0	0	0.2068	-0.0730	0	0	-45.43	0	0	45.43	-42.15	-1914.8
-0.1210	0.1994	0	0	0.1994	-0.0704	0	0	-43.82	0	0	43.82	-41.15	-1802.99
-0.1167	0.1923	0	0	0.1923	-0.0679	0	0	-42.26	0	0	42.26	-40.15	-1696.7
-0.1125	0.1854	0	0	0.1854	-0.0655	0	0	-40.76	0	0	40.76	-39.15	-1595.67
-0.1085	0.1788	0	0	0.1788	-0.0631	0	0	-39.31	0	0	39.31	-38.15	-1499.67
-0.1046	0.1724	0	0	0.1724	-0.0609	0	0	-37.91	0	0	37.91	-37.15	-1408.46
-0.1009	0.1662	0	0	0.1662	-0.0587	0	0	-36.57	0	0	36.57	-36.15	-1321.83
-0.0973	0.1603	0	0	0.1603	-0.0566	0	0	-35.26	0	0	35.26	-35.15	-1239.56
-0.0938	0.1546	0	0	0.1546	-0.0546	0	0	-34.01	0	0	34.01	-34.15	-1161.47
-0.0904	0.1490	0	0	0.1490	-0.0526	0	0	-32.80	0	0	32.80	-33.15	-1087.36
-0.0872	0.1437	0	0	0.1437	-0.0507	0	0	-31.63	0	0	31.63	-32.15	-1017.05
-0.0841	0.1386	0	0	0.1386	-0.0489	0	0	-30.51	0	0	30.51	-31.15	-950.352
-0.0811	0.1336	0	0	0.1336	-0.0472	0	0	-29.42	0	0	29.42	-30.15	-887.109
-0.0782	0.1289	0	0	0.1289	-0.0455	0	0	-28.38	0	0	28.38	-29.15	-827.16
-0.0754	0.1242	0	0	0.1242	-0.0439	0	0	-27.37	0	0	27.37	-28.15	-770.35
-0.0727	0.1198	0	0	0.1198	-0.0423	0	0	-26.39	0	0	26.39	-27.15	-716.532
-0.0701	0.1155	0	0	0.1155	-0.0408	0	0	-25.45	0	0	25.45	-26.15	-665.566
-0.0676	0.1114	0	0	0.1114	-0.0393	0	0	-24.55	0	0	24.55	-25.15	-617.318
-0.0652	0.1074	0	0	0.1074	-0.0379	0	0	-23.67	0	0	23.67	-24.15	-571.66

-0.0629	0.1036	0	0	0.1036	-0.0366	0	0	-22.83	0	0	22.83	-23.15	-528.468
-0.0606	0.0999	0	0	0.0999	-0.0353	0	0	-22.01	0	0	22.01	-22.15	-487.626
-0.0584	0.0963	0	0	0.0963	-0.0340	0	0	-21.23	0	0	21.23	-21.15	-449.022
-0.0564	0.0929	0	0	0.0929	-0.0328	0	0	-20.47	0	0	20.47	-20.15	-412.547
-0.0543	0.0895	0	0	0.0895	-0.0316	0	0	-19.74	0	0	19.74	-19.15	-378.1
-0.0524	0.0863	0	0	0.0863	-0.0305	0	0	-19.04	0	0	19.04	-18.15	-345.584
-0.0505	0.0833	0	0	0.0833	-0.0294	0	0	-18.36	0	0	18.36	-17.15	-314.903
-0.0487	0.0803	0	0	0.0803	-0.0283	0	0	-17.71	0	0	17.71	-16.15	-285.97
-0.0470	0.0774	0	0	0.0774	-0.0273	0	0	-17.08	0	0	17.08	-15.15	-258.698
-0.0453	0.0746	0	0	0.0746	-0.0264	0	0	-16.47	0	0	16.47	-14.15	-233.007
-0.0437	0.0720	0	0	0.0720	-0.0254	0	0	-15.88	0	0	15.88	-13.15	-208.818
-0.0421	0.0694	0	0	0.0694	-0.0245	0	0	-15.31	0	0	15.31	-12.15	-186.058
-0.0406	0.0669	0	0	0.0669	-0.0236	0	0	-14.77	0	0	14.77	-11.15	-164.655
-0.0392	0.0645	0	0	0.0645	-0.0228	0	0	-14.24	0	0	14.24	-10.15	-144.541
-0.0378	0.0622	0	0	0.0622	-0.0220	0	0	-13.73	0	0	13.73	-9.15	-125.653
-0.0364	0.0600	0	0	0.0600	-0.0212	0	0	-13.24	0	0	13.24	-8.15	-107.928
-0.0351	0.0578	0	0	0.0578	-0.0204	0	0	-12.77	0	0	12.77	-7.15	-91.307
-0.0339	0.0558	0	0	0.0558	-0.0197	0	0	-12.31	0	0	12.31	-6.15	-75.7346
-0.0326	0.0538	0	0	0.0538	-0.0190	0	0	-11.88	0	0	11.88	-5.15	-61.1572
-0.0315	0.0519	0	0	0.0519	-0.0183	0	0	-11.45	0	0	11.45	-4.15	-47.5234
-0.0303	0.0500	0	0	0.0500	-0.0177	0	0	-11.04	0	0	11.04	-3.15	-34.7847
-0.0293	0.0482	0	0	0.0482	-0.0170	0	0	-10.65	0	0	10.65	-2.15	-22.8947
-0.0282	0.0465	0	0	0.0465	-0.0164	0	0	-10.27	0	0	10.27	-1.15	-11.8089
-0.0272	0.0448	0	0	0.0448	-0.0158	0	0	-9.90	0	0	9.90	-0.15	-1.48532
-0.0262	0.0432	0	0	0.0432	-0.0153	0	0	-9.55	0	0	9.55	0.85	8.116372
-0.0253	0.0417	0	0	0.0417	-0.0147	0	0	-9.21	0	0	9.21	1.85	17.03448
-0.0244	0.0402	0	0	0.0402	-0.0142	0	0	-8.88	0	0	8.88	2.85	25.30551
-0.0235	0.0388	0	0	0.0388	-0.0137	0	0	-8.56	0	0	8.56	3.85	32.96428
-0.0227	0.0374	0	0	0.0374	-0.0132	0	0	-8.26	0	0	8.26	4.85	40.04389
-0.0219	0.0360	0	0	0.0360	-0.0127	0	0	-7.96	0	0	7.96	5.85	46.57592
-0.0211	0.0348	0	0	0.0348	-0.0123	0	0	-7.68	0	0	7.68	6.85	52.5904
-0.0203	0.0335	0	0	0.0335	-0.0118	0	0	-7.40	0	0	7.40	7.85	58.11593
-0.0196	0.0323	0	0	0.0323	-0.0114	0	0	-7.14	0	0	7.14	8.85	63.17974
-0.0189	0.0312	0	0	0.0312	-0.0110	0	0	-6.88	0	0	6.88	9.85	67.80773

-0.0182	0.0300	0	0	0.0300	-0.0106	0	0	-6.64	0	0	6.64	10.85	72.02455
-0.0176	0.0290	0	0	0.0290	-0.0102	0	0	-6.40	0	0	6.40	11.85	75.85363
-0.0170	0.0279	0	0	0.0279	-0.0099	0	0	-6.17	0	0	6.17	12.85	79.31728
-0.0163	0.0269	0	0	0.0269	-0.0095	0	0	-5.95	0	0	5.95	13.85	82.4367
-0.0158	0.0260	0	0	0.0260	-0.0092	0	0	-5.74	0	0	5.74	14.85	85.23204
-0.0152	0.0250	0	0	0.0250	-0.0088	0	0	-5.53	0	0	5.53	15.85	87.72246
-0.0147	0.0241	0	0	0.0241	-0.0085	0	0	-5.34	0	0	5.34	16.85	89.92617
-0.0141	0.0233	0	0	0.0233	-0.0082	0	0	-5.15	0	0	5.15	17.85	91.86045
-0.0136	0.0225	0	0	0.0225	-0.0079	0	0	-4.96	0	0	4.96	18.85	93.54174
-0.0131	0.0217	0	0	0.0217	-0.0076	0	0	-4.79	0	0	4.79	19.85	94.98563
-0.0127	0.0209	0	0	0.0209	-0.0074	0	0	-4.61	0	0	4.61	20.85	96.20692
-0.0122	0.0201	0	0	0.0201	-0.0071	0	0	-4.45	0	0	4.45	21.85	97.21968
-0.0118	0.0194	0	0	0.0194	-0.0069	0	0	-4.29	0	0	4.29	22.85	98.03723
-0.0114	0.0187	0	0	0.0187	-0.0066	0	0	-4.14	0	0	4.14	23.85	98.67223
-0.0110	0.0180	0	0	0.0180	-0.0064	0	0	-3.99	0	0	3.99	24.85	99.13667
-0.0106	0.0174	0	0	0.0174	-0.0061	0	0	-3.85	0	0	3.85	25.85	99.44192
-0.0102	0.0168	0	0	0.0168	-0.0059	0	0	-3.71	0	0	3.71	26.85	99.59876
-0.0098	0.0162	0	0	0.0162	-0.0057	0	0	-3.58	0	0	3.58	27.85	99.6174
-0.0095	0.0156	0	0	0.0156	-0.0055	0	0	-3.45	0	0	3.45	28.85	99.50751
-0.0091	0.0150	0	0	0.0150	-0.0053	0	0	-3.33	0	0	3.33	29.85	99.27825
-0.0088	0.0145	0	0	0.0145	-0.0051	0	0	-3.21	0	0	3.21	30.85	98.93829
-0.0085	0.0140	0	0	0.0140	-0.0049	0	0	-3.09	0	0	3.09	31.85	98.49584
-0.0082	0.0135	0	0	0.0135	-0.0048	0	0	-2.98	0	0	2.98	32.85	97.95863
-0.0079	0.0130	0	0	0.0130	-0.0046	0	0	-2.88	0	0	2.88	33.85	97.33402
-0.0076	0.0125	0	0	0.0125	-0.0044	0	0	-2.77	0	0	2.77	34.85	96.62894
-0.0073	0.0121	0	0	0.0121	-0.0043	0	0	-2.67	0	0	2.67	35.85	95.84992
-0.0071	0.0117	0	0	0.0117	-0.0041	0	0	-2.58	0	0	2.58	36.85	95.00315
-0.0068	0.0112	0	0	0.0112	-0.0040	0	0	-2.49	0	0	2.49	37.85	94.09447
-0.0066	0.0108	0	0	0.0108	-0.0038	0	0	-2.40	0	0	2.40	38.85	93.12939
-0.0063	0.0105	0	0	0.0105	-0.0037	0	0	-2.31	0	0	2.31	39.85	92.11309
-0.0061	0.0101	0	0	0.0101	-0.0036	0	0	-2.23	0	0	2.23	40.85	91.05046
-0.0059	0.0097	0	0	0.0097	-0.0034	0	0	-2.15	0	0	2.15	41.85	89.94612
-0.0057	0.0094	0	0	0.0094	-0.0033	0	0	-2.07	0	0	2.07	42.85	88.80441
-0.0055	0.0090	0	0	0.0090	-0.0032	0	0	-2.00	0	0	2.00	43.85	87.6294

-0.0053	0.0087	0	0	0.0087	-0.0031	0	0	-1.93	0	0	1.93	44.85	86.42493
-0.0051	0.0084	0	0	0.0084	-0.0030	0	0	-1.86	0	0	1.86	45.85	85.19461
-0.0049	0.0081	0	0	0.0081	-0.0029	0	0	-1.79	0	0	1.79	46.85	83.94182
-0.0047	0.0078	0	0	0.0078	-0.0028	0	0	-1.73	0	0	1.73	47.85	82.66975
-0.0046	0.0075	0	0	0.0075	-0.0027	0	0	-1.67	0	0	1.67	48.85	81.38136
-0.0044	0.0073	0	0	0.0073	-0.0026	0	0	-1.61	0	0	1.61	49.85	80.07946
-0.0043	0.0070	0	0	0.0070	-0.0025	0	0	-1.55	0	0	1.55	50.85	78.76665
-0.0041	0.0068	0	0	0.0068	-0.0024	0	0	-1.49	0	0	1.49	51.85	77.44537
-0.0040	0.0065	0	0	0.0065	-0.0023	0	0	-1.44	0	0	1.44	52.85	76.11791
-0.0038	0.0063	0	0	0.0063	-0.0022	0	0	-1.39	0	0	1.39	53.85	74.7864
-0.0037	0.0061	0	0	0.0061	-0.0021	0	0	-1.34	0	0	1.34	54.85	73.45282
-0.0035	0.0058	0	0	0.0058	-0.0021	0	0	-1.29	0	0	1.29	55.85	72.11902
-0.0034	0.0056	0	0	0.0056	-0.0020	0	0	-1.25	0	0	1.25	56.85	70.78673
-0.0033	0.0054	0	0	0.0054	-0.0019	0	0	-1.20	0	0	1.20	57.85	69.45753
-0.0032	0.0052	0	0	0.0052	-0.0018	0	0	-1.16	0	0	1.16	58.85	68.1329
-0.0031	0.0050	0	0	0.0050	-0.0018	0	0	-1.12	0	0	1.12	59.85	66.81423
-0.0030	0.0049	0	0	0.0049	-0.0017	0	0	-1.08	0	0	1.08	60.85	65.50277
-0.0028	0.0047	0	0	0.0047	-0.0017	0	0	-1.04	0	0	1.04	61.85	64.1997
-0.0027	0.0045	0	0	0.0045	-0.0016	0	0	-1.00	0	0	1.00	62.85	62.90609
-0.0026	0.0044	0	0	0.0044	-0.0015	0	0	-0.97	0	0	0.97	63.85	61.62293
-0.0026	0.0042	0	0	0.0042	-0.0015	0	0	-0.93	0	0	0.93	64.85	60.35112
-0.0025	0.0041	0	0	0.0041	-0.0014	0	0	-0.90	0	0	0.90	65.85	59.0915
-0.0024	0.0039	0	0	0.0039	-0.0014	0	0	-0.87	0	0	0.87	66.85	57.84481
-0.0023	0.0038	0	0	0.0038	-0.0013	0	0	-0.83	0	0	0.83	67.85	56.61175
-0.0022	0.0036	0	0	0.0036	-0.0013	0	0	-0.80	0	0	0.80	68.85	55.39292
-0.0021	0.0035	0	0	0.0035	-0.0012	0	0	-0.78	0	0	0.78	69.85	54.1889
-0.0021	0.0034	0	0	0.0034	-0.0012	0	0	-0.75	0	0	0.75	70.85	53.00017
-0.0020	0.0033	0	0	0.0033	-0.0012	0	0	-0.72	0	0	0.72	71.85	51.82718
-0.0019	0.0031	0	0	0.0031	-0.0011	0	0	-0.70	0	0	0.70	72.85	50.67033
-0.0018	0.0030	0	0	0.0030	-0.0011	0	0	-0.67	0	0	0.67	73.85	49.52996
-0.0018	0.0029	0	0	0.0029	-0.0010	0	0	-0.65	0	0	0.65	74.85	48.40638
-0.0017	0.0028	0	0	0.0028	-0.0010	0	0	-0.62	0	0	0.62	75.85	47.29983
-0.0017	0.0027	0	0	0.0027	-0.0010	0	0	-0.60	0	0	0.60	76.85	46.21053
-0.0016	0.0026	0	0	0.0026	-0.0009	0	0	-0.58	0	0	0.58	77.85	45.13867

-0.0015	0.0025	0	0	0.0025	-0.0009	0	0	-0.56	0	0	0.56	78.85	44.0844
-0.0015	0.0024	0	0	0.0024	-0.0009	0	0	-0.54	0	0	0.54	79.85	43.04782
-0.0014	0.0024	0	0	0.0024	-0.0008	0	0	-0.52	0	0	0.52	80.85	42.02901
-0.0014	0.0023	0	0	0.0023	-0.0008	0	0	-0.50	0	0	0.50	81.85	41.02804
-0.0013	0.0022	0	0	0.0022	-0.0008	0	0	-0.48	0	0	0.48	82.85	40.04492
-0.0013	0.0021	0	0	0.0021	-0.0007	0	0	-0.47	0	0	0.47	83.85	39.07966
-0.0012	0.0020	0	0	0.0020	-0.0007	0	0	-0.45	0	0	0.45	84.85	38.13224
-0.0012	0.0020	0	0	0.0020	-0.0007	0	0	-0.43	0	0	0.43	85.85	37.20262
-0.0011	0.0019	0	0	0.0019	-0.0007	0	0	-0.42	0	0	0.42	86.85	36.29073
-0.0011	0.0018	0	0	0.0018	-0.0006	0	0	-0.40	0	0	0.40	87.85	35.3965
-0.0011	0.0018	0	0	0.0018	-0.0006	0	0	-0.39	0	0	0.39	88.85	34.51983
-0.0010	0.0017	0	0	0.0017	-0.0006	0	0	-0.37	0	0	0.37	89.85	33.6606
-0.0010	0.0016	0	0	0.0016	-0.0006	0	0	-0.36	0	0	0.36	90.85	32.81869
-0.0010	0.0016	0	0	0.0016	-0.0006	0	0	-0.35	0	0	0.35	91.85	31.99396
-0.0009	0.0015	0	0	0.0015	-0.0005	0	0	-0.34	0	0	0.34	92.85	31.18626
-0.0009	0.0015	0	0	0.0015	-0.0005	0	0	-0.32	0	0	0.32	93.85	30.39542
-0.0009	0.0014	0	0	0.0014	-0.0005	0	0	-0.31	0	0	0.31	94.85	29.62126
-0.0008	0.0014	0	0	0.0014	-0.0005	0	0	-0.30	0	0	0.30	95.85	28.86362
-0.0008	0.0013	0	0	0.0013	-0.0005	0	0	-0.29	0	0	0.29	96.85	28.12229
-0.0008	0.0013	0	0	0.0013	-0.0004	0	0	-0.28	0	0	0.28	97.85	27.39708
-0.0007	0.0012	0	0	0.0012	-0.0004	0	0	-0.27	0	0	0.27	98.85	26.68778
-0.0007	0.0012	0	0	0.0012	-0.0004	0	0	-0.26	0	0	0.26	99.85	25.99418
-0.0007	0.0011	0	0	0.0011	-0.0004	0	0	-0.25	0	0	0.25	100.85	25.31607
-0.0007	0.0011	0	0	0.0011	-0.0004	0	0	-0.24	0	0	0.24	101.85	24.65322
-0.0006	0.0011	0	0	0.0011	-0.0004	0	0	-0.23	0	0	0.23	102.85	24.00541
-0.0006	0.0010	0	0	0.0010	-0.0004	0	0	-0.23	0	0	0.23	103.85	23.37241
-0.0006	0.0010	0	0	0.0010	-0.0004	0	0	-0.22	0	0	0.22	104.15	23.18537
											6937.81		-430608

Appendix B:

Pierson-Moskowitz Spectrum and Simulation of Wave Profile Spectra

son-Moskowitz Spectrum

f	a	f^-5	.25(F/Fo)^	S(f)	H(f)
005	0.000499	3.2E+11	0.000	0.000	0.000
015	0.000499	1.32E+09	0.000	0.000	0.000
025	0.000499	1.02E+08	0.000	0.000	0.000
035	0.000499	19039686	0.000	0.000	0.000
045	0.000499	5419228	0.000	0.000	0.000
055	0.000499	1986948	0.000	0.033	0.052
065	0.000499	861853	0.005	2.185	0.418
075	0.000499	421399.2	0.051	10.683	0.924
085	0.000499	225374.8	0.164	18.483	1.216
095	0.000499	129235.5	0.314	20.278	1.274
105	0.000499	78352.62	0.460	18.014	1.200
115	0.000499	49717.67	0.583	14.483	1.076
125	0.000499	32768	0.680	11.123	0.943
135	0.000499	22301.35	0.753	8.386	0.819
145	0.000499	15601.27	0.808	6.295	0.710
155	0.000499	11177.42	0.849	4.741	0.616
165	0.000499	8176.742	0.881	3.596	0.536
175	0.000499	6092.699	0.904	2.752	0.469
185	0.000499	4614.678	0.923	2.127	0.412
195	0.000499	3546.72	0.937	1.660	0.364

ulation of Wave Profile Spectra

t 0

(n)	H(n)	R(N)	H(n)/2	k(n)x	2πf(n)t	ε(n)	x
005	0.020	0.085915	0.01	0	0	0.539892	0.0086
015	0.035	0.461009	0.017321	0	0	2.896978	-0.0168
025	0.045	0.117504	0.022361	0	0	0.738397	0.0165
035	0.053	0.531466	0.026458	0	0	3.339735	-0.0259
045	0.060	0.512596	0.03	0	0	3.221156	-0.0299
055	0.066	0.468369	0.033166	0	0	2.943232	-0.0325
065	0.072	0.752495	0.036056	0	0	4.728676	0.0006
075	0.077	0.475417	0.03873	0	0	2.987524	-0.0383
085	0.082	0.619123	0.041231	0	0	3.890571	-0.0302
095	0.087	0.898269	0.043589	0	0	5.644722	0.0350
105	0.092	0.162746	0.045826	0	0	1.022693	0.0239
115	0.096	0.285209	0.047958	0	0	1.792253	-0.0105
125	0.100	0.091939	0.05	0	0	0.577745	0.0419
135	0.104	0.895785	0.051962	0	0	5.629114	0.0412
145	0.108	0.946702	0.053852	0	0	5.949077	0.0509
155	0.111	0.592852	0.055678	0	0	3.725482	-0.0465
165	0.115	0.306644	0.057446	0	0	1.926953	-0.0200
175	0.118	0.888423	0.059161	0	0	5.582848	0.0452
185	0.122	0.405514	0.060828	0	0	2.548251	-0.0504
195	0.125	0.28428	0.06245	0	0	1.786418	-0.0134
						η	-0.0506

Appendix C:
Motion Response Spectrum

surge

f	f^-5	(f/fo)^-4	exp(f/fo)^-4	x	s(f)	Area (s(f)*Δf)		H(f)	R(N)	ΣN	T	FI	H/2
0.005	3.20E+11	7.875E+04	0.00	0.000499	0.000	0.00000	5.5902	0.0000	0.421	14.9372	200.0000	966724.99	0
0.015	1.32E+09	9.723E+02	0.00	0.000499	0.000	0.00000	5.5902	0.0000	0.531	11.8347	66.6667	11804460.98	0
0.025	1.02E+08	1.260E+02	0.00	0.000499	0.000	0.00000	5.5902	0.0000	0.499	12.6016	40.0000	12898478.60	2.009E-33
0.035	1.90E+07	3.280E+01	0.00	0.000499	0.000	0.00000	5.5902	0.0000	0.042	151.3805	28.5714	10413940.82	1.724E-08
0.045	5.42E+06	1.200E+01	0.00	0.000499	0.001	0.00001	5.5902	0.0081	0.762	8.2488	22.2222	4183528.05	0.0040614
0.055	1.99E+06	5.379E+00	0.00	0.000499	1.193	0.01193	5.5902	0.3089	0.083	75.5088	18.1818	12214727.32	0.1544705
0.065	8.62E+05	2.757E+00	0.03	0.000499	13.711	0.13711	5.5902	1.0473	0.694	9.0534	15.3846	6837018.36	0.5236639
0.075	4.21E+05	1.556E+00	0.14	0.000499	30.111	0.30111	5.5902	1.5521	0.987	6.3637	13.3333	13510116.15	0.7760282
0.085	2.25E+05	9.429E-01	0.31	0.000499	34.638	0.34638	5.5902	1.6646	0.508	12.3589	11.7647	6663256.19	0.8323221
0.095	1.29E+05	6.043E-01	0.47	0.000499	30.329	0.30329	5.5902	1.5577	0.747	8.4127	10.5263	2799866.95	0.7788262
0.105	7.84E+04	4.049E-01	0.60	0.000499	23.591	0.23591	5.5902	1.3738	0.261	24.1161	9.5238	9694095.48	0.6868938
0.115	4.97E+04	2.814E-01	0.70	0.000499	17.469	0.17469	5.5902	1.1822	0.994	6.3228	8.6957	12993335.33	0.5910788
0.125	3.28E+04	2.016E-01	0.78	0.000499	12.721	0.12721	5.5902	1.0088	0.957	6.5645	8.0000	13575206.43	0.5044044
0.135	2.23E+04	1.482E-01	0.83	0.000499	9.256	0.09256	5.5902	0.8605	0.061	102.9406	7.4074	12318474.70	0.4302486
0.145	1.56E+04	1.113E-01	0.87	0.000499	6.780	0.06780	5.5902	0.7365	0.007	910.1171	6.8966	10038141.41	0.3682425
0.155	1.12E+04	8.527E-02	0.90	0.000499	5.018	0.05018	5.5902	0.6336	0.385	16.3279	6.4516	7279776.92	0.3168118
0.165	8.18E+03	6.641E-02	0.92	0.000499	3.759	0.03759	5.5902	0.5484	0.631	9.9652	6.0606	4480881.66	0.274184
0.175	6.09E+03	5.248E-02	0.94	0.000499	2.850	0.02850	5.5902	0.4775	0.891	7.0557	5.7143	1774100.03	0.2387465
0.185	4.61E+03	4.202E-02	0.95	0.000499	2.187	0.02187	5.5902	0.4183	0.446	14.0925	5.4054	603048.22	0.2091423
0.195	3.55E+03	3.404E-02	0.96	0.000499	1.698	0.01698	5.5902	0.3685	0.126	49.8838	5.1282	2801562.28	0.1842682
0.205	2.76E+03	2.787E-02	0.97	0.000499	1.332	0.01332	5.5902	0.3265	0.542	11.5897	4.8780	2801562.28	0.1632404

	ω	RAO	RAO²	Sx(f)
2.7951	0.03142	#DIV/0!	#DIV/0!	#DIV/0!
2.7951	0.09426	#DIV/0!	#DIV/0!	#DIV/0!
2.7951	0.1571	############	8.111E+66	1636.8382
2.7951	0.21994	############	1.806E+16	268.46116
2.7951	0.28278	137.6952730	18959.988	15.636931
2.7951	0.34562	7.0513643	49.721738	59.320836
2.7951	0.40846	0.8319166	0.6920852	9.4893146
2.7951	0.4713	0.8321619	0.6924934	20.851659
2.7951	0.53414	0.2976755	0.0886107	3.0692968
2.7951	0.59698	0.1069501	0.0114383	0.3469072
2.7951	0.65982	0.3435464	0.1180242	2.7843262
2.7951	0.72266	0.4459509	0.1988722	3.4740404
2.7951	0.7855	0.4620065	0.21345	2.7153386
2.7951	0.84834	0.4212952	0.1774896	1.6427896
2.7951	0.91118	0.3476424	0.1208552	0.8194139
2.7951	0.97402	0.2564177	0.06575	0.3299657
2.7951	1.03686	0.1609174	0.0258944	0.0973331
2.7951	1.0997	0.0650395	0.0042301	0.0120559
2.7951	1.16254	0.0225812	0.0005099	0.0011152
2.7951	1.22538	0.1071604	0.0114834	0.0194957
2.7951	1.28822	0.1094449	0.0119782	0.0159594

Heave

f	f^-5	(f/fo)^-4	exp(f/fo)^-4	x	s(f)	Area (s(f)*Δf)		H(f)	R(N)	ΣN	T	FI	H/2
0.005	3.20E+11	7.875E+04	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.948	6.6277	200.0000	966724.99	0
0.015	1.32E+09	9.723E+02	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.992	6.3350	66.6667	11804460.98	0
0.025	1.02E+08	1.260E+02	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.193	32.6054	40.0000	12898478.60	2.009E-33
0.035	1.90E+07	3.280E+01	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.258	24.3863	28.5714	10413940.82	1.724E-08
0.045	5.42E+06	1.200E+01	0.00	0.000499	0.001	0.00001	5.5902	0.008	0.294	21.3985	22.2222	4183528.05	0.0040614
0.055	1.99E+06	5.379E+00	0.00	0.000499	1.193	0.01193	5.5902	0.309	0.699	8.9952	18.1818	12214727.32	0.1544705
0.065	8.62E+05	2.757E+00	0.03	0.000499	13.711	0.13711	5.5902	1.047	0.421	14.9325	15.3846	6837018.36	0.5236639
0.075	4.21E+05	1.556E+00	0.14	0.000499	30.111	0.30111	5.5902	1.552	0.670	9.3750	13.3333	13510116.15	0.7760282
0.085	2.25E+05	9.429E-01	0.31	0.000499	34.638	0.34638	5.5902	1.665	0.879	7.1493	11.7647	6663256.19	0.8323221
0.095	1.29E+05	6.043E-01	0.47	0.000499	30.329	0.30329	5.5902	1.558	0.440	14.2974	10.5263	2799866.95	0.7788262
0.105	7.84E+04	4.049E-01	0.60	0.000499	23.591	0.23591	5.5902	1.374	0.365	17.2205	9.5238	9694095.48	0.6868938
0.115	4.97E+04	2.814E-01	0.70	0.000499	17.469	0.17469	5.5902	1.182	0.768	8.1875	8.6957	12993335.33	0.5910788
0.125	3.28E+04	2.016E-01	0.78	0.000499	12.721	0.12721	5.5902	1.009	0.174	36.0784	8.0000	13575206.43	0.5044044
0.135	2.23E+04	1.482E-01	0.83	0.000499	9.256	0.09256	5.5902	0.860	0.295	21.2700	7.4074	12318474.70	0.4302486
0.145	1.56E+04	1.113E-01	0.87	0.000499	6.780	0.06780	5.5902	0.736	0.527	11.9148	6.8966	10038141.41	0.3682425
0.155	1.12E+04	8.527E-02	0.90	0.000499	5.018	0.05018	5.5902	0.634	0.170	36.9861	6.4516	7279776.92	0.3168118
0.165	8.18E+03	6.641E-02	0.92	0.000499	3.759	0.03759	5.5902	0.548	0.181	34.7791	6.0606	4480881.66	0.274184
0.175	6.09E+03	5.248E-02	0.94	0.000499	2.850	0.02850	5.5902	0.477	0.676	9.3023	5.7143	1774100.03	0.2387465
0.185	4.61E+03	4.202E-02	0.95	0.000499	2.187	0.02187	5.5902	0.418	0.796	7.8913	5.4054	603048.22	0.2091423
0.195	3.55E+03	3.404E-02	0.96	0.000499	1.698	0.01698	5.5902	0.369	0.994	6.3214	5.1282	2801562.28	0.1842682
0.205	2.76E+03	2.787E-02	0.97	0.000499	1.332	0.01332	5.5902	0.326	0.889	7.0682	4.8780	2801562.28	0.1632404

f	f^-5	(f/fo)^-4	exp(f/fo)^-4	x	s(f)	Area (s(f)*Δf)		H(f)	R(N)	ΣN	T	moment kN.m	H/2
0.005	3.20E+11	7.875E+04	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.365	17.2059	200.0000	757728700	0
0.015	1.32E+09	9.723E+02	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.390	16.0965	66.6667	735214000	0
0.025	1.02E+08	1.260E+02	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.687	9.1504	40.0000	803773000	2.009E-33
0.035	1.90E+07	3.280E+01	0.00	0.000499	0.000	0.00000	5.5902	0.000	0.261	24.1206	28.5714	648119000	1.724E-08
0.045	5.42E+06	1.200E+01	0.00	0.000499	0.001	0.00001	5.5902	0.008	0.558	11.2678	22.2222	258492000	0.0040614
0.055	1.99E+06	5.379E+00	0.00	0.000499	1.193	0.01193	5.5902	0.309	0.991	6.3423	18.1818	760921000	0.1544705
0.065	8.62E+05	2.757E+00	0.03	0.000499	13.711	0.13711	5.5902	1.047	0.040	156.7554	15.3846	428127000	0.5236639
0.075	4.21E+05	1.556E+00	0.14	0.000499	30.111	0.30111	5.5902	1.552	0.270	23.2379	13.3333	842116000	0.7760282
0.085	2.25E+05	9.429E-01	0.31	0.000499	34.638	0.34638	5.5902	1.665	0.772	8.1364	11.7647	413443000	0.8323221
0.095	1.29E+05	6.043E-01	0.47	0.000499	30.329	0.30329	5.5902	1.558	0.679	9.2535	10.5263	176989000	0.7788262
0.105	7.84E+04	4.049E-01	0.60	0.000499	23.591	0.23591	5.5902	1.374	0.794	7.9097	9.5238	605575000	0.6868938
0.115	4.97E+04	2.814E-01	0.70	0.000499	17.469	0.17469	5.5902	1.182	0.705	8.9102	8.6957	810190000	0.5910788
0.125	3.28E+04	2.016E-01	0.78	0.000499	12.721	0.12721	5.5902	1.009	0.467	13.4616	8.0000	846197000	0.5044044
0.135	2.23E+04	1.482E-01	0.83	0.000499	9.256	0.09256	5.5902	0.860	0.582	10.7886	7.4074	767422000	0.4302486
0.145	1.56E+04	1.113E-01	0.87	0.000499	6.780	0.06780	5.5902	0.736	0.459	13.7046	6.8966	624589000	0.3682425
0.155	1.12E+04	8.527E-02	0.90	0.000499	5.018	0.05018	5.5902	0.634	0.834	7.5367	6.4516	451992000	0.3168118
0.165	8.18E+03	6.641E-02	0.92	0.000499	3.759	0.03759	5.5902	0.548	0.658	9.5559	6.0606	277064000	0.274184
0.175	6.09E+03	5.248E-02	0.94	0.000499	2.850	0.02850	5.5902	0.477	0.335	18.7416	5.7143	108091000	0.2387465
0.185	4.61E+03	4.202E-02	0.95	0.000499	2.187	0.02187	5.5902	0.418	0.077	82.1007	5.4054	40140100	0.2091423
0.195	3.55E+03	3.404E-02	0.96	0.000499	1.698	0.01698	5.5902	0.369	0.104	60.1577	5.1282	177094000	0.1842682
0.205	2.76E+03	2.787E-02	0.97	0.000499	1.332	0.01332	5.5902	0.326	0.535	11.7461	4.8780	2801562.28	0.1632404

	ω	RAO (radian)	RAO²	Sx(f)
2.7951	0.03142	#DIV/0!	#DIV/0!	#DIV/0!
2.7951	0.09426	#DIV/0!	#DIV/0!	#DIV/0!
2.7951	0.1571	############	1.898E+63	0.3830759
2.7951	0.21994	############	4.362E+12	0.0648306
2.7951	0.28278	2.1390919	4.5757143	0.0037737
2.7951	0.34562	0.1108266	0.0122825	0.0146538
2.7951	0.40846	0.0131694	0.0001734	0.002378
2.7951	0.4713	0.0131294	0.0001724	0.0051905
2.7951	0.53414	0.0046790	2.189E-05	0.0007583
2.7951	0.59698	0.0017137	2.937E-06	8.907E-05
2.7951	0.65982	0.0054421	2.962E-05	0.0006987
2.7951	0.72266	0.0070537	4.975E-05	0.0008691
2.7951	0.7855	0.0073070	5.339E-05	0.0006792
2.7951	0.84834	0.0066606	4.436E-05	0.0004106
2.7951	0.91118	0.0054903	3.014E-05	0.0002044
2.7951	0.97402	0.0040414	1.633E-05	8.197E-05
2.7951	1.03686	0.0025260	6.381E-06	2.398E-05
2.7951	1.0997	0.0010061	1.012E-06	2.885E-06
2.7951	1.16254	0.0003816	1.457E-07	3.185E-07
2.7951	1.22538	0.0017201	2.959E-06	5.023E-06
2.7951	1.28822	0.0000278	7.724E-10	1.029E-09